Systems Science Approaches to Visualize, Model, and Explore Stigma's Role in Socially Patterning HIV Risk Among Gay, Bisexual, and Other Men Who Have Sex With Men (GBMSM) in Europe

by

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Dedication

To my community of families, both biological and logical, ancestors and people who have walked down heavy life roads that nobody should have to travel! I appreciate all your love, support, and kindness during this doctoral program. It has been an experience of both personal and professional growth and learning for which I am in completely grateful. I am in total gratitude to my community that supported getting me to this finish! I stand on the shoulders of giants, both known and unknown! The best dissertation is a done dissertation!

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Abstract

The inequitable and growing prevalence and incidence of HIV in Europe among GBMSM is an enduring characteristic of the HIV epidemic and makes the continent an important geographical region to study from a global health perspective. Stigma is a significant barrier to, or fundamental cause of, limited equity in HIV prevention and treatment. Yet, current framings of HIV risk and interventions may not adequately incorporate how stigma adversely affects GBMSM's mental health, constrains their social behavior, influences their sexual decision-making, and hinders access to prevention technologies. Developing and enhancing individual-level interventions that require GBMSM to cope with the structural determinants might reduce HIV risk, but only to a limited degree.

A mostly unexplored question is: how does the complexity of structural stigmatization of GBMSM's identities influence one's capabilities, freedoms, and motivations to prevent HIV? Such a question studies each of these separately but, more importantly, explores how each intersecting and overlapping process, in tandem, influences HIV risk, and infection. The call for new theoretical and methodological approaches to address the multitude of factors that influence HIV has been around for over a decade. Moreover, computational and statistical modelling of complex and interacting pathways is now a possibility given advances in data visualization, computational power, and analytic approaches. Such new methods include complex systems theory, and agent-based and multi-level modelling.

The objective of this dissertation was to portray how HIV risk among European GBMSM is socially patterned by structural stigma (i.e., policies) to improve public health's conceptualization, estimation, and quantification of stigma's role in perpetuating HIV. The objective of the dissertation was informed by three specific aims: (1) **Specific aim one**: to develop a visualization of HIV risk that reflects stigma's role in the epidemic among European GBMSM using Complex Systems Theory; (2) **Specific aim two:** to understand to what extent "stigmatizing policies" influence HIV prevalence and other direct and indirect risk factors among European GBMSM in a simulated agent-based model; and (3) **Specific aim three:** to assess to what extent countries' LGBTQ+ policies interact with downstream individual-level factors to influence GBMSM's HIV serostatus using real-world European survey data.

In aim one, I examined how the elements within the system and their interactions served to (re)produce HIV risk. The visualization indicated that there are numerous overlapping and interacting factors that shape HIV risk, of which policies play an instrumental role. In aim two, I used an agent-based model (ABM) to study an *a priori* pathway of the complex systems visualization developed in aim one. The ABM indicated that dynamic and interactional processes, in the form of stigmatizing policies, shape homonegativity and sexual behaviors to influence HIV risk and infection. Aim two informed the research question for aim three. For aim three, I used real-world survey data to examine how country-level sexual and gender minority (SGM) policies (e.g., equality laws, anti-discrimination, gender identity protections, etc.) were associated with GBMSM's HIV status. The multi-level modeling indicated that SGM policies interacted with downstream behaviors and mental health to increase the probability of an HIV positive serostatus. **In totality, this dissertation contributed new insights on HIV equity by demonstrating how**

stigmatizing policies can shape the emergence of HIV risk through its influence on the dynamic and interactional relationships of diverse risk factors.

Chapter 1: Introduction

European gay, bisexual, and other men who have sex with men as a "key population" for HIV risk and prevention

Globally "key populations," such as gay, bisexual, and other men who have sex with men (GBMSM) are understood to be most at risk for HIV (Centers for Disease Control and Prevention, 2017; Joint United Nations Programme on HIV/AIDS, 2014). Given a similar global phenomenon across social and cultural contexts there may be underlying mechanisms of action that shape HIV risk. From a global health perspective, Europe is an important geographical region to study. The inequitable prevalence and incidence of HIV in Europe is skewed toward GBMSM. The proportion of HIV attributed to sex between men in Europe was 34% in 2008, increased to 41% in 2015 and decreased to 37% in 2017 (World Health Organization, 2018). Sex between men accounts for the highest number of new HIV infections in Europe (World Health Organization, 2018). GBMSM account for nearly 50% of new HIV cases in Western Europe (European Union (EU) and European Economic Areas (EEA)) (World Health Organization, 2018). In the European Union (EU)/European Economic Area (EEA) there has been a slight decline in HIV infection trends (World Health Organization, 2018). Certain Western countries, such as the Netherlands, Spain, Norway, the United Kingdom (UK), Belgium experienced large decreases in infection from 2008 to 2017. To support HIV prevention efforts the UK, France, Norway, Spain, Denmark, Sweden, and Switzerland have guidelines for pre-exposure prophylaxis (PrEP) (PrEP in Europe Initiative, 2016). More alarming statistics are seen in Eastern Europe. In 2017, there were 159,420 persons diagnosed with HIV in Europe, of which 82% were in Eastern European, a region that accounts

for 50% of Europe's total population (Gokengin et al., 2018; World Health Organization, 2018). In the region, the HIV cases increased 68% from 77,228 cases in 2016 to 130,861 cases in 2017 among all persons. In 2017 there were 51.1 cases of HIV per 100,000 people in Eastern Europe, as compared to 6.9 cases per 100,000 in Western Europe (World Health Organization, 2018). Male-to-male sexual transmissions of HIV increased eight-fold and continues to rise in the region (World Health Organization, 2018). Since 2008 HIV rates have over doubled in places such .as Bulgaria, Cyprus and Lithuania, and increased over 50% in countries such as Czechia, Hungary, Poland, and Malta. As some examples, in Czechia, of the 1,741 persons living with HIV (PLHIV), 64% were GBMSM (Joint United Nations Programme on HIV/AIDS, 2016). In 2012, the Serbian Institute of Public Health estimated that 66% of HIV cases in Serbia arose from male-to-male sexual contact (Обреновић et al., 2013). In 2013, a study among GBMSM in Serbia estimated an 8.3% prevalence rate of HIV (Baros, 2018). In Croatia, from 2007-2015, 80% of persons entering into care for HIV treatment were GBMSM (Laval, 2016). The Russian Federation has the largest number of persons living with HIV in Europe, at an estimated 1.16 million (Beyrer et al., 2017). A recent respondent-driven sample (RDS) study of GBMSM in Russia indicated that the RDS-adjusted prevalence was 11.6%, well above the government's 4-6% statistic (Krishnaratne et al., 2016).

These statistics portray the burden of HIV acquisition borne by GBMSM in the European continent. GBMSM experience the brunt of the HIV epidemic in Europe, and particularly in Eastern Europe. Such disparities require attention to understand the root causes of HIV risk among GBMSM in Europe.

Stigma as a fundamental cause of HIV inequities

An overarching factor that influences HIV risk factors, across levels of the socioecological

model (described in the section *Risk factors for HIV across the socioecological model*), is stigma. According to Erving Goffman, "society establishes the means of categorizing persons and the complement of attributes felt to be ordinary and natural for members of each of these categories" (Goffman, 1963). Stigma arises from the process of "Othering." "Othering" is a sociological and psychological process in that individuals or groups become classified as different from what is considered "mainstream" or "normal" because of their social identities, and their intersections (Brons, 2015). "Othering" then creates differential (stigmatized) treatment of the "other" (GBMSM) across levels of the socioecological model (Brons, 2015). For GBMSM, their sexual identity and behaviors are the factors that are stigmatized. Thus, the "othering" process of GBMSM's socially constructed identities are policed and treated negatively by law, policies, norms, and interpersonal relationships.

Social Identity Theory posits that individuals are affected by their social identities, their membership (whether perceived or real) in social groups and the cultural and social norms that (de)values these groups. (Tajfel, 1974). Social identity categories relate to the cultural and societal productions of identity, such as sexual orientation, gender identity, race, and the intersectionality of those identities that can create additional stigmatization (Crenshaw, 1989; Graham et al., 2011; Meyer, 2003; Pearson & Geronimus, 2011). The "othering" shapes GBSMSM's lived experiences, and their interpersonal, community, institutional, and structural relationships.

The "othering" and stigmatization of GBMSM has been present for centuries. Richard Krafft-Ebing, a prominent psychiatrist, published *Psychopathia Sexualis* in 1886. In it, Krafft-Ebing "elucidates" the qualities of the "homosexual." Ebing discusses, "The fact that there is no doubt about the pathological basis of many cases of inverted sexual instinct (known today as homosexuality);" depicting the way that "homosexuals" were defined at the time (Von Krafft-

Ebing, 2001). In addition to pathologizing "homosexuality," GBMSM were defined as "aberrations" and "criminals." These hegemonic understandings of GBMSM would be the prevailing views well into the 20th century. The stigmatization would be applied in ways such as criminalizing same-sex behaviors, treating homosexuality as a mental disorder, and denying rights such as access to marriage (Burton, 2015; Chang, 2015; The New York Times, 2018). However, in *Psychopathia Sexualis,* one of Krafft-Ebing's participants elaborated on the effects of stigmatization and "othering" in a letter to the psychiatrist for the 1886 book,

> "You have no idea what a constant struggle we all—particularly those of us who have the most mind and finest feelings—must endure, and how I suffer under the prevailing false ideas about us and our so—called 'immorality...' Under all circumstances the phenomenon is anomalous; but the word 'pathological' (which Krafft-Ebing uses) conveys another meaning, which I cannot think suits this phenomenon…I will allow, *a priori,* that, among homosexuals, a far higher proportion of cases of insanity, or nervous exhaustion, etc., may be observed than in other normal men. Does this increased nervousness necessarily depend upon the character of homosexuality, or is it not, in the majority of cases, to be ascribed to the effect of the laws and the prejudices of society…" (Von Krafft-Ebing, 2001)

In Europe, GBMSM experience numerous interrelated "othering" processes. For example, European GBMSM report gay-related victimization including verbal assaults, physical violence, and threats of violence in all nations (Petrou & Lemke, 2017). GBMSM in Eastern European nations have even more experiences with victimization (Petrou & Lemke, 2017). Research from Russia shows how laws and ordinances "other" GBMSM, which in turn elevates their needs related to HIV services (Hylton et al., 2017; Knight, 2019). Similar processes of stigma, across levels of the socioecological model, are occurring in numerous European nations (Baros, 2018; Bränström et al., 2016; Kohler, 2018; Quinn, 2006; Stojanovski et al., 2019; Stojisavljevic et al., 2017; Judit Takács, 2006; Woodcock, 2016)

Stigma is a process that is enacted individually, interpersonally, communally, institutionally, and structurally to "other" those viewed outside the "norm." **For this dissertation,**

stigma is conceptualized as a fundamental cause—a factor that influences the behaviors of GBMSM and hinders HIV prevention efforts (Hatzenbuehler, 2009; Hatzenbuehler et al., 2013; Phelan et al., 2010). Given that stigma operates across numerous areas including policy, community norms, and interpersonal relationships conceptualizing its specific relationships to the processes that lead to HIV risk is critical and yet remains a challenge.

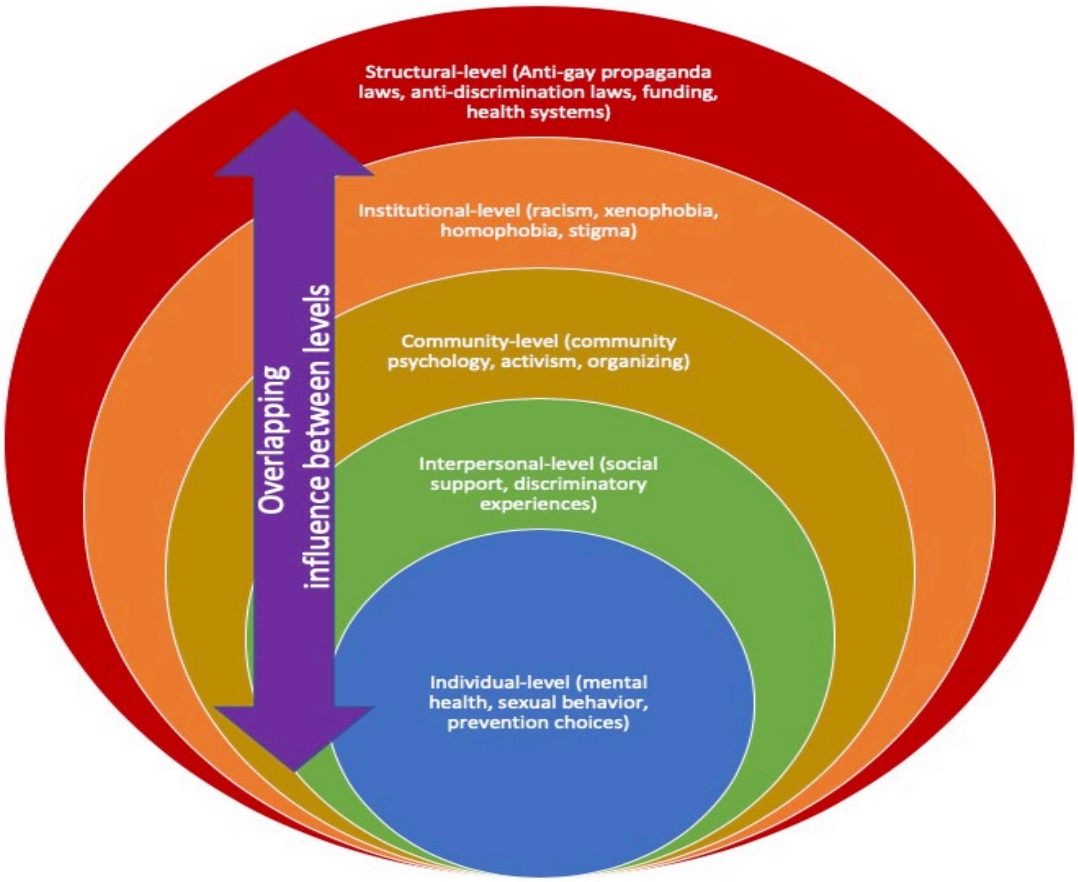
The socioecological model

The socioecological model is a useful starting point to understand how stigma may play a role in patterning HIV inequities. According to the socioecological model there are structural/policy; community; institutional; interpersonal; and individual-level factors that influence health (Mcleroy et al., 1988). The first, structural, is a macrosystem level of influence and usually includes policies or laws. For example, anti-gay propaganda laws, like those in Russia, could influence organizational abilities to provide services. The second level is the institutional level. According to Merriam-Webster an institution is “a significant practice, relationship, or organization in a society or culture” (Merriam Webster Inc, 2019). Institutional-level factors encompass social, cultural, customary norms and precedence—institutions—that intersect to create systems of oppression and stigmatization. These institutions are norms and values—for this dissertation characterized as homophobia, xenophobia, sexism, misogyny, amongst others (stigma)—that serve to "other" and stigmatize GBMSM. Then, there are community-level influences, which are those that exist at the level of groups, populations, and social networks. A community-level influence could be friends and kin networks, religious groups, the existence of community centers, and many more. The fourth level is the interpersonal level, which are influences that occur during social interactions, such as peer norms, peer pressure, social support, and healthy or unhealthy relationships, etc. For example, if one shared their HIV status with others,

they could receive support when they might have issues, or not, if social support is of low quality. The last level is the individual-level, which are defined as characteristics within the individual. These are factors, such as knowledge, attitudes, skills, and mental health. For example, in-depth knowledge about sexual and behavioral risk factors for HIV could assist with prevention efforts.

Figure 1, portrays the socioecological model and potential risk factors for HIV. The risk factors included are not all encompassing, and many other factors could be included. Using all the levels: structural; organizational/institutional; community; interpersonal; and individual helps to contextualize the risk factors for HIV. Understanding HIV, through a socioecological perspective, means there are reinforcing processes, reverse causation, and transactions between the individuals, communities, organizations, and laws and policies. The socioecological model is important for the study of HIV because it "views behaviors as being affected by, and affecting the social environment" (Mcleroy et al., 1988). As Mcleory et al. state "Ecological models are systems models, but they differ from traditional systems models by viewing patterned behavior—of individuals or aggregates—as the outcomes of interest" (Mcleroy et al., 1988). The socioecological model, as shown in Figure 1, begins to portray the patterned outcome of HIV inequity experienced by GBMSM. The various influences of risk factors for HIV within and across the different levels guide this dissertation. This dissertation focuses on elucidating how structural stigma (i.e., policies) lead to the intermediary and downstream determinants that influence HIV risk and infection.

Figure 1. Socioecological model of risk factors for HIV



Risk factors for HIV across the socioecological model

The socioecological model situates health behavior, and ultimately health outcomes, as a patterned effect of numerous determinants across multiple levels, which can influence and reinforce each other. This section outlines some of the known risk factors identified in the research literature within each level of the socioecological model that relate to HIV risk and infection. The risk factors identified are not meant to be exhaustive. Instead, they serve to be representative of those most researched (e.g., systematic reviews, meta-analyses, etc.). However, a challenge with the socioecological model is that it limits the portrayal of the exact relationships between risk factors within each level of the socioecological model, across different levels, or how these interactions are intertwined. This dissertation focuses on understanding how individual risk

behaviors described in the literature, such as condom use, HIV testing, etc., are influenced by stigma. Specifically, in aim one, I developed a visualization to elucidate the interactions and pathways that stigmatizing policies and norms influence, and their relationship to downstream health behaviors that shape HIV risk among European GBMSM using Complex Systems Theory (*Chapter 2. A Web of Risk: Visualizing stigma's influence on the HIV risk environment among gay, bisexual, and other men who have sex with men in Europe).*

Individual-level risk factors for HIV

To date, much of the research related to understanding HIV risk and interventions have focused on individual-level behaviors. Anatomically and biologically, HIV is spread through the transmission of semen and/or blood across mucous membranes from the person living with HIV (PLHIV) who has uncontrolled virus to the HIV-negative individual. Current per-act probabilities of acquiring HIV, without incorporating any preventive efforts, indicate that the greatest risk stems from receptive anal intercourse (138 infections per 10,000 exposures), then 63 infections per 10,000 exposures for injection drug use, followed by 11 infections per 10,000 exposures for insertive anal intercourse, 8 infections per 10,000 exposures for receptive penile-vaginal intercourse, and 4 infections per 10,000 exposures for insertive penile-vaginal intercourse (Centers for Disease Control and Prevention, 2015). The estimates for receptive and insertive anal intercourse will become important values as described in aim two (Chapter 3. An agent-based model to explore stigmatizing policies' role in social patterning HIV risk and infection among European gay, bisexual, and other men who have sex with men).

Adding nuance, these estimates can vary due to numerous individual-level strategies that exist to mitigate and reduce risk, in many cases, to zero. For example, research on condom use indicates that there is upwards of 90% reduction in risk if the condoms are used consistently and

correctly (Pinkerton & Abramson, 1997). However, a meta-analysis review suggests that condoms are often used inconsistently or incorrectly (e.g., not leaving space at the tip), and that erectile issues also occur (Sanders et al., 2012). Other studies have similarly described improper fit and issues with condoms breaking or not working perfectly (Hernández-Romieu et al., 2014) This "imperfect" use can reduce condom effectiveness to 50-70%, calling attention to the need for additional prevention strategies (Pinkerton & Abramson, 1997). The use of antiretrovirals (ARVs) for treatment and prevention have both been shown to greatly reduce HIV risk. In many studies, the estimates of risk are essentially zero for those on pre-exposure prophylaxis (PrEP, an HIV prevention medicine) and taking their medicine as required (Anderson et al., 2010; Grant et al., 2010; Marcus et al., 2016; Volk et al., 2015). Similarly, for PLHIV and who have an undetectable HIV viral load their risk of onward transmission is reduced to zero (M. S. Cohen et al., 2011; Rodger et al., 2019; Rodger, Cambiano, Bruun, Vernazza, Collins, van Lunzen, et al., 2016).

While numerous individual-level strategies for HIV prevention exist, many individual-level factors can also alter the capacities of GBMSM to participate in HIV risk-reducing behaviors. Research indicates that poor mental health can reduce the use of condoms, shape the frequency of sexual partners, increase substance use, and limit the ability to access and adhere to biomedical interventions (Lee et al., 2016; Rosario et al., 2011; Storholm et al., 2016; Velloza et al., 2020; Wade et al., 2017; Wang et al., 2017). Unfortunately, SGM individuals, including GBMSM, are two times more likely to meet criteria for depression, 38% among SGM vs. 19% in non-SGM ($p<0.01$) (measured by Beck Depression Inventory-II) and anxiety, 26% among SGM vs. 12% non-SGM ($p<0.01$) (measured by Generalized Anxiety Disorder scale), (J. M. Cohen et al., 2016). Hatzenbuehler et al. found that gay men and lesbian women, as compared to heterosexuals, had higher levels of anxiety, depression, panic, and post-traumatic stress disorders (all measured by

AUDADIS-IV) (Hatzenbuehler, 2011; Hatzenbuehler et al., 2009, 2010). A study across 38 European countries indicated high internalized homonegativity (i.e., negative self-perceptions of sexual identity) among GBMSM, which was negatively associated with HIV testing, sexually transmitted infection (STI) testing, use of condoms, and seeing their physicians (European Centre for Disease Prevention & Control, 2013). Research also directly links poor mental health to increased risk for HIV. For example, Mimiaga et al. found that psychosocial factors such as depression and substance use are *causally* related to increased HIV vulnerability. The hazards of becoming diagnosed with HIV increases as more psychosocial conditions become present (Mimiaga et al., 2015).

These mental health issues create complexity in our understanding of HIV risk factors and need to be considered within conceptualizations of HIV risk. While this section focuses on mental health, it is not the only individual-level factor related to HIV risk. There are additional individual-level factors, not described here that may impact one's HIV risk, such as knowledge about HIV, attitudes toward HIV, wealth and income, and many more. In addition to the individual-level, many interpersonal-level factors interact to facilitate or inhibit the individual-level HIV prevention strategies and the subsequent social patterning of HIV risk and infection among GBMSM.

Interpersonal-level risk factors for HIV

Individual-level factors are enmeshed within interpersonal-level risk factors, which can alter the role that individual-level factors play. Evidence indicates that experiences of discrimination are related to poorer mental health outcomes. One study, among 577 lesbian, gay, bisexual men and women from the National Epidemiologic Survey on Alcohol and Related Conditions (NESARC), reported that GBMSM who experienced discrimination (measured by Experiences of Discrimination Scale (EODS)) demonstrated higher odds of panic disorder (AOR

24.90, 95% CI 2.47-251.48), although the confidence interval was wide (Lee et al., 2016). Identity-based victimization, such as bullying of LGBTQ+ youth has been found to significantly adversely influence mental health outcomes (Poteat et al., 2017; Russell & Fish, 2016).

These issues are also salient in Europe, which has diverse institutions, norms, policies, and laws. A cross-European analysis of 181,495 GBMSM in 38 countries indicated that men who experienced gay-related hostility and violence had higher internalized homonegativity (i.e., negative views about one's sexual orientation identity) (Berg et al., 2013). The elevated homonegativity was associated with reduced access and use of condoms (Berg et al., 2013). Another European-wide study among GBMSM showed that higher internalized homonegativity was strongly associated with lower levels of condom use with non-steady sexual partners in the last 12 months (Ross et al., 2013). Other research has shown that homophobia and homophobic experiences are associated with sexual behaviours that elevate GBMSM's risk for HIV (Jeffries IV et al., 2013).

In the same ECDC study with 181,495 GBMSM, Eastern European men reported the highest percentages of victimization, abuse, and violence, as compared to Western European nations (European Centre for Disease Prevention & Control, 2013). In North Macedonia, 40% of 208 sexual and gender minority (SGM) persons reported being assaulted, as compared to 15% among 188 non-SGM persons (Stojanovski et al., 2018). Similarly, SGM, as compared to non-SGM, reported higher levels of rumination and social anxiety. SGM's experiences of discrimination accounted for 95% of the rumination and 41% of the variation for social anxiety (Stojanovski et al., 2018). A geographically and ethnically diverse qualitative study with 71 SGM community members, and 10 NGO staff serving them, in North Macedonia has indicated that stigma shapes mental health and fear of accessing mental health services (Stojanovski, King, et

al., 2021). Similar issues of interpersonal stigma and its influence on mental health and fear of accessing services are seen in other European countries, such as Romania, Hungary, Russia, and Bosnia & Herzegovina (Hylton et al., 2017; Quinn, 2006; Stojisavljevic et al., 2017; Takács et al., 2013; Takács, 2006). These lines of research show the interconnectedness of mental health, HIV risk, and the role that stigma may play.

The interpersonal-level factors that influence individual factors add nuance to our understanding of HIV risk factors. Linking these interpersonal issues to the individual-level is essential to understanding the interrelated effects that socially pattern HIV risk and infection. For example, discrimination can lead to poor mental health, which (as described above) can shape health behaviors that put GBMSM at risk for HIV. The list and relationships described within this section are not exhaustive. Other interpersonal factors such as social support, family relationship, etc. can influence the interrelatedness of relationships that lead to (or reduce) HIV risk and HIV infection. Simply, this section serves to further portray how the interpersonal-level factors intersect with the individual-level to socially pattern HIV risk and infection among GBMSM in Europe. In addition to the factors described above, in the next section I describe community-level factors that can also serve to socially pattern HIV risk and infection.

Community-level risk factors for HIV

Community-level factors are important to take into consideration when understanding HIV risk and infection. There is an extensive body of literature portraying how social networks may play a role in HIV prevention. Social Network Strategy (SNS) is an evidence-supported method to engage and encourage persons to test for HIV and to receive prevention and treatment services, as applicable, by working with individuals and their social networks (Campbell et al., 2018; Fuqua et al., 2012; Heckathorn, 1997; Kimbrough et al., 2009; Lightfoot et al., 2018; Little et al., 2014;

McCree et al., 2013; Smyrnov et al., 2018). SNS is based on the idea that members of social networks share the same or similar risks and sexual risk behaviors for HIV. SNS relies on recruiters to engage with their social networks to convince persons in their network to test for HIV. In an U.S.-based systematic review, Stojanovski et al. (2021) found a great of diversity in the network indices, a standard SNS measurement that averages the number of network associates recruited by the total number of recruiters. In the studies reviewed, the network index ranged from 0.8 to 10.6 (Stojanovski et al., 2021). The wide range of the indices portrays variation in the ability of recruiters to recruit network associates to test for HIV. SNS has been studied in Eastern Europe and found to be a useful strategy in Greece and Ukraine to locate those who might be living with or at elevated risk of HIV (Nikolopoulos et al., 2016; Smyrnov et al., 2018). Engaging with social and community networks is an important consideration for HIV prevention efforts, which can shape GBMSM's individual and interpersonal risk for HIV.

Community activism and advocacy are important considerations that can shape HIV and SGM related policies within countries. Recent scholarship indicates how transnational networks of NGOs, SGM communities, and activism in Europe helps to improve the lives of SGM peoples (Ayoub, 2016). However, variation exists in the success of these networks and activism in achieving rights for SGM, depending on each country's political, social, and historical context (Ayoub, 2016). For example, SGM activists in Czechia embraced technocratic and professionalized social movement models and were dependent on international donors, which hindered bottom-up and community-led grassroots activism (O'Dwyer, 2013). Activism by PLHIV and other SGM in North Macedonia worked to ensure government funding for HIV treatment after the withdrawal of the Global Fund for Malaria, Tuberculosis, and HIV/AIDS funding was withdrawn (Open Society Foundation, 2017). The lack of a strong community-led

response in Serbia and Montenegro was related to cuts in funding and a lack of a coherent government strategy to address the shortfall (Open Society Foundation, 2017). Community-level factors become key elements that shape other intermediary risk factors for HIV, such as access to HIV testing and services, and the policies that govern the lives of SGM people.

There are many other community-level factors such as community connectedness, social capital, and sexual networks that can also influence HIV risk. Additional research is necessary to fully investigate the role of activism and its relationship to HIV, especially on the European continent. While such activism and community engagement are important to consider, these are not the focus of this dissertation. Some of the community-level factors will be portrayed in the complex systems visualization of HIV in Chapter 2 (aim one) of this dissertation. Nonetheless, community-level factors play a role in socially patterning HIV risk and infection through other interrelated processes, such as getting legislation passed, securing funding, and sharing and supporting HIV knowledge and testing. However, the community-level factors are influenced by institutional and structural factors outlined in the next sections.

Institutional/organizational-level risk factors for HIV

Further complicating our understanding of HIV risk and infection are the institutional-level factors. For this dissertation an institution will be defined as: "a significant practice, relationship, or organization in a society or culture" (Merriam Webster Inc, 2019). Institutional-level factors encompass social, cultural, customary norms and precedence—institutions—that create systems of oppression or privilege depending on one's social identities. These institutions include norms and values that align with homophobia, sexism, misogyny, transphobia, and numerous other institutions that have persisted over time and space. Issues of homophobia, nationalism, and hateful rhetoric have created challenges for SGM rights. These institutions shape the experiences of

GBMSM in ways that stigmatize. For example, homophobic attitudes are rampant in parts of Europe, driving GBMSM to hide, which in turn can limit their access to quality health services (Beyrer et al., 2017; Hylton et al., 2017; Stojanovski et al., 2019; Stojisavljevic et al., 2017; Takács et al., 2013; Takács, 2006). National rhetoric and policymaking in many nations on the European continent utilize homophobic values. For example, Switzerland explicitly denies the right to marriage, same-gender full adoption, and access to in-vitro fertilization to same-gender couples (Swiss Info, 2005). In Russia, publications or information regarding non-heterosexual orientation targeted toward minors is banned due to anti-gay propaganda laws (Knight, 2019). In addition, prominent Russian scholars support SGM "research" that are not aligned with current global frameworks, and instead pathologize the SGM community (Moss, 2021). The institution of homophobia seems to play a role in perpetuating state-sanctioned violence against SGM, which can create barriers to HIV and adjacent services.

Institutions, such as xenophobia, are also particularly salient on the European continent. Roma sexual minorities experience additional marginalization due to their intersectional identities—being an ethnic minority and a SGM. Recent scholarship has noted the particular challenges that Roma have in meeting their health needs on the European continent, and particularly as related to sexual health and HIV (European Union Agency for Fundamental Rights, 2012; Mihailov, 2012). In a cohort study from 1985 to 2008 among Roma in Barcelona, Spain, the incidence rate of AIDS was 104.1 per 100,000 person-years of follow-up (95% CI 80.1-128.0), as compared to 45 cases of AIDS per person-years of follow-up in Barcelona's general population (Casals et al., 2011). In North Macedonia, Roma LGBTQ+ experience acute sexual health needs due to limited services in their neighborhoods and challenges with the loss of Global Fund funding (Stojanovski et al., 2019).

In addition, norms and vocabulary regarding sexuality and gender identity have been exported from Western cultures, which creates additional institutional challenges safeguarding rights, activism, health, and ultimately HIV infection. Concepts of sexuality and the vocabulary used (e.g., gay, trans gender, queer) have not been fully incorporated or understood within the local narratives and discourse in many European nations (Kulpa & Mizielinska, 2016). As an example, the word 'queer,' which has English meaning—although confusion still exists—may be meaningless in non-English speaking geographies. There is also an East/West divide in framing of SGM issues within the European continent. Shannon Woodcock portrays how Western donors have power in setting the agendas for development of the SGM community (Woodcock, 2016). These donor institutions have a large role in shaping programs and policies to "address" SGM issues faced on the European continent without full representation of the SGM community (Woodcock, 2016). This is also an issue with setting public health policies and agendas. Milevska Kostova et al. indicated that developing coherent national public health policies and systems in Southeastern Europe has largely been exported and dictated by international funders such as the World Bank (Milevska Kostova et al., 2018). Many other institutional-level factors may exist, such as stigma in healthcare institutions, which can influence GBMSM's risk of HIV. For the purposes of this dissertation, and as described earlier, institutions—in the forms of racism, xenophobia, homophobia and donors—individually, and in concert, serve to contextualize our framing and understanding of HIV risk and infection on the European continent. The next section further describes the social patterning of HIV among GBMSM as influenced by policies and laws.

Structural/policy-level risk factors for HIV

Structural and policy-level risk factors also serve to socially pattern HIV risk and infection among GBMSM. Among the 577 LGB persons in the NESARC, Hatzenbuehler uncovered that

those who lived in States with no anti-discrimination or hate crime protection laws that included sexual orientation, were over three times more likely to suffer from depression (OR=3.0, 95% CI(1.8, 5.0)), generalized anxiety disorder (OR=3.3, 95%CI(1.9, 5.9)), panic disorder (OR=3.9, 95% CI(1.9, 8.3), and social phobia (OR=3.8, 95%CI(1.9, 7.5)), and were at 4.8 times the odds of comorbid psychiatric disorders (all measured by AUDADIS-IV) (Hatzenbuehler et al., 2009). In a European study of 38 countries, GBMSM living in countries without legal rights and protections for LGBTQ+ persons were found to have the highest homonegativity scores (Berg et al., 2013). Linking these findings to previously described research portrays how structural stigma and marginalization are linked to poor mental health, which in turn can elevate one's HIV risk through sexual behavior changes.

Policies, politics, and funding—all structural-level factors—can serve to either improve or hinder responses to HIV, and thus socially pattern HIV risk and infection among GBMSM. For example, in Russia, after the passage of the anti-gay propaganda law, GBMSM in Moscow described a fear of disclosure that limited HIV prevention and health seeking behaviors (Wirtz et al., 2014). Other studies have shown that stigmatizing policies and norms may hinder HIV prevention efforts (Hylton et al., 2017; Lunze et al., 2017; Pachankis et al., 2017a; Stojanovski et al., 2019). Rhodes et al. coined the term "risk environment" to encompass the many structural and cultural factors that produce a risk of poor health (Rhodes & Simic, 2005). Some of these factors include anti-gay laws, laws criminalizing same sex intercourse, and bans on Pride parades—all of which arise from institutional-level factors such as homophobia, sexism, and misogyny. The risk environment concept, in the context of HIV, is a useful heuristic to focus the attention on the social processes and structures that individuals must contend with and participate in, rather than on the individual themselves. This aligns with other frameworks, such as Jedi Public Health, that

similarly call for understanding how poor health is structurally rooted and tied to individuals social identities, and the contingencies of those identities, rather on the individual themselves (Geronimus et al., 2016). The multitude of factors that stigmatizing policies and laws can influence is vast. Therefore, better incorporation of the structural determinants of health are needed in HIV prevention research, interventions, and policy development, which this dissertation aims to address.

Challenges with the socioecological model

The socioecological model is an important theory that begins to outline interrelated factors that shape health inequities. However, the socioecological model does not adequately supply us with information about what factors within each level of the socioecological model are related to each other, the directionality of the relationships, and the extent to which various factors mutually reinforce one another. There is a lack of specificity of the direct and indirect relationships between risk factors and across levels in the socioecological model. The incomplete visualization of the pathways to HIV risk and diagnosis limits our understanding of the various intersecting and overlapping pathways that socially pattern HIV risk and diagnosis among GBMSM. The lack of information on the exact relationships of risk factors and across levels creates a barrier in guiding conceptualizations, providing estimates, and creating interventions. **Lacking clear conceptualizations of pathways of relationships restricts our ability to understand the holistic, dynamic and emergent nature of HIV risk that disproportionately burdens GBMSM in Europe, and arguably globally**.

Research and interventions tend to shy away from the complexity of public and population health issues because it is difficult to understand and statistically model, let alone intervene. One way to better understand the health ramifications and complexity of stigma, as related to HIV risk

and infection, is Complex Systems Theory. Complex Systems Theory may offer a solution to the problem by explicitly outlining the intersecting, interacting, and overlapping pathways that can lead to HIV risk and diagnosis. Combining the numerous overlapping and intersecting risk factors for HIV and estimating their effects is crucial for an appropriate conceptualization and response to HIV prevention and achieving global goals.

Complex systems theory

Given the advancements in mapping, computational power and modeling approaches, Complex Systems Theory may play an important role in elucidating specific pathways to HIV risk. With the robust nature of HIV research and science, since the 1980s, we have extensive information about various components of the dynamic pathways involved in the system that socially patterns HIV risk and diagnosis. Recognizing this complexity permits for the study of patterns, and interrelationships, and interactions that allows for the development of a holistic portrayal of population health inequities as related to HIV. Use of this theory also aligns with Rhodes et al. concept of the risk environment (Rhodes & Simic, 2005).

Complex Systems Theory is a way of thinking that recognizes the intricacy of systems that people live, work, and play in. Complex systems do not strictly focus on cause-and-effect relationships within the model (although these are a component). Rather, complex systems focus on the elements within a system, their interactions, and **the emerging effect of these interactions** (Diez Roux, 2011; Thurner et al., 2018). Complex systems are networks with multiple layers that evolve and change over time, while also operating across multiple pathways, multiple domains, and multiple levels. Complex systems also involve reinforcing processes that interact with one another and create dependencies and feedback loops to different parts within the system. How do

such processes and interactions serve to socially pattern HIV risk in ways that European GBMSM people experience the burden of infection and risk on the continent?

A salient argument to use complex systems theory comes from sociologist Allen Barton who stated in 1968:

> "For the last thirty years, empirical social research has been dominated by the sample survey. But as usually practiced, using random sampling of individuals, the survey is a sociological meatgrinder, tearing the individual from his social context and guaranteeing that nobody in the study interacts with anyone else in it. ... If our aim is to understand people's behavior rather than simply to record it, I want to know about primary groups, neighborhoods, organizations, social circles, and communities; about interaction, communication, role expectations, and social control." (Barton, 1968).

There is a building chorus of researchers and academics calling for additional use of systems science methods. The January 2019 issue of the *American Journal of Public Health (AJPH)* has recently called for increased attention to the upstream fundamental causes of population health disparities and new methods to model, predict, and address them. Palmer et al., from a paper in the issue noted, "A fair amount of research has investigated mid- and down-stream social determinants to health…but research elucidating upstream social determinants (e.g., governance and policy) of health pathways that lead to health disparities is needed" (Palmer et al., 2019). And as Brown et al. stated in the January 2019 American Journal of Public Health issue, "The vision for health disparities research is to promote intervention science that addresses the structural drivers of health disparities through multi-sectoral collaboration." Complex Systems Theory is a novel approach that can help identify how the structural drivers, such as stigma, create emerging mid and down-stream social determinants that lead to HIV risk and diagnosis among GBMSM in Europe.

Dissertation rationale, specific aims & hypotheses

To date much of our conceptualizations of HIV prevention have focused the individual-level. Attempts to alter individual-level behaviors have included promoting abstinence; using condoms; biomedical prevention efforts such as PrEP and post-exposure prophylaxis (PEP), Undetectable=Untransmittable; reducing frequency of sexual partners; and reducing substance use and sharing of needles (Centers for Disease Control and Prevention, 2018). While needed, improved conceptualizations of HIV risk and methodological approaches in research are required to better appraise the spectrum of interactional and intersectional processes that elevate GBMSM's risk for HIV diagnosis, which emanate from higher order structural determinants, such as stigma and policies.

While the evidence is growing about stigma's role in HIV, little is known about the various pathways it creates and to what extent stigma shapes the interaction of risk factors. Understanding how stigma influences different risk factors, and their relationships to one another, is a gap in the research that needs addressing. Examining stigma's dynamic role is critical given the body of research portraying how discrimination, mental health, and sexual behavior are all intertwined in HIV research, practice, and policy. To address gaps in knowledge, this dissertation's objective is to portray how HIV risk among European GBMSM is socially patterned by stigma. The objective of this dissertation is addressed by three specific aims and their hypotheses.

1) **Specific aim one**: To develop a conceptual model and visualization of HIV risk that reflects stigma's role in the epidemic among European GBMSM using Complex Systems Theory. For this specific aim, a systematic review and systems mapping software were used to create a visualization that portrays the complexity of factors that are interrelated

and socially pattern HIV risk toward GBMSM populations. Chapter 2 addresses this first specific aim.

2) **Specific aim two:** To understand to what extent "stigmatizing policies" influence HIV prevalence and other direct and indirect risk factors among European GBMSM in a simulated agent-based model. For specific aim two, an algorithmic computational agent-based model (ABM) using the Properties, Action, Rules, Time, and Environment framework was developed (Hammoud, 2015). The ABM explored how changes in policies can shape experiences of discrimination, mental health, and sexual risk behaviors, and ultimately HIV diagnosis. Chapter 3 addresses this second specific aim, which is focused on hypothesis generation for future research (for Chapter 4) rather than hypothesis testing.
3) **Specific aim three:** To assess to what extent countries' SGM policies interact with downstream individual-level factors to influence GBMSM's HIV serostatus using European empirical data. For the final aim, I used data from a European survey of GBMSM and multi-level modeling to explore how stigmatizing policies interact with downstream anxiety/depression and sexual risk behaviors to shape HIV diagnoses among GBMSM in Europe. Chapter 4 addresses this third specific aim. I hypothesize that stigmatizing policies will interact with downstream health behaviors to elevate the probability of an HIV positive serostatus among European GBMSM.

Chapter 5 provides a discussion and reflection on the overall objective of the dissertation and implications for public health research, practice and policy for HIV research in Europe. This final section of this dissertation highlights key findings, discusses the relevance of the dissertation to field of HIV and public health, and proposes future research trajectories.

Chapter 2. A Web of Risk: Visualizing Stigma's Influence on the HIV Risk Environment Among Gay, Bisexual, and Other Men Who Have Sex With Men in Europe

Abstract:

Given the increasing cases of HIV in Europe, particularly among gay, bisexual, and other men who have sex with men (GBMSM), it is vital to explore the processes that shape its emergence. HIV risk factors operate in interactional, bi-directional, and potentially reinforcing ways. Complex Systems Theory is a useful theory to explore the dynamic nature of HIV risk. I conducted a systematic review of the stigma and HIV risk literature in Europe to develop a conceptual model using Complex Systems Theory to understand stigma's roles in socially patterning HIV among GBMSM. The systematic review interrogated the research literature to determine the upstream and downstream factors, intersections, and processes shaping GBMSM's HIV risk in Europe. I used the review to develop a conceptual model and visualization of HIV risk. The thematic analysis indicated that stigma helps create a web of complex and reinforcing processes that negatively shape GBMSM's HIV risk and prevention efforts. The conceptual model of the HIV risk environment for European GBMSM portrays an ecosystem of factors that shape the emergence of HIV to socially pattern the vulnerability that European GBMSM experience. These findings call attention for the need to include more upstream interventions that halt the processes from occurring rather than coping with the downstream impacts.

Introduction

"Key populations," such as gay, bisexual, and other men who have sex with men (GBMSM) have the highest chance of acquiring HIV in their lifetime. In Western Europe, 50% of new HIV diagnoses are among GBMSM (World Health Organization, 2018). In the European Union (E.U.)/European Economic Area (EEA), HIV infections have been declining (World Health Organization, 2018). From 2008 to 2017, countries, such as the Netherlands, Spain, Norway, the U.K., and Belgium, experienced decreases in infection rates (World Health Organization, 2018). However, rates of HIV are rising in Eastern Europe. The rising rates of HIV in some areas of Europe make it a critical geographic area from a global health perspective (Avert, 2019).

Of the 159,420 persons diagnosed with HIV in Europe in 2017 82% were in Eastern Europe—a region that accounts for 50% of Europe's total population (Gokengin et al., 2018; World Health Organization, 2018). Since 2008, HIV rates have doubled in Bulgaria, Cyprus, and Lithuania, and increased over 50% in countries such as Czechia, Hungary, Poland, and Malta (World Health Organization, 2018). Among GBMSM, HIV transmissions increased eight-fold in Eastern Europe from 2008-2017 (Avert, 2019; International AIDS Society, 2018; World Health Organization, 2018).

Current per-act probabilities of acquiring HIV, without incorporating any preventive efforts, show the highest risk stems from receptive anal intercourse: 138 infections per 10,000 exposures and 11 infections per 10,000 exposures for insertive anal intercourse (Centers for Disease Control and Prevention, 2015). There is upwards of a 90% reduction in HIV risk if condoms are used consistently and correctly (Pinkerton & Abramson, 1997). However, a meta-review reported that people use condoms inconsistently or incorrectly (e.g., not leaving space at the tip) (Sanders et al., 2012). The improper use and issues of fit or breaking reduces condom's

effectiveness to 50-70% (Pinkerton & Abramson, 1997). These probabilities may also be shaped or altered by other factors, such as stigma and access to services, such as pre-exposure prophylaxis (PrEP).

Systemic stigma is a well-documented, influential factor for HIV risk that may have particular relevance in GBMSM communities. Stigma is a social process that marginalizes populations of people because of their non-"normative" social identities. Many models aim to incorporate the structural and social determinants to health, which is vital for HIV research. The Health Stigma and Discrimination Framework emphasizes the social, cultural, political, and economic structures that shape stigma itself, and not merely the stigma enacted interpersonally (Stangl et al., 2019). Rhodes et al.'s concept of the "[HIV] risk environment" shifts the focus toward the social and structural processes at play, providing a useful heuristic to identify how stigma shapes various HIV risk factors (Rhodes & Simic, 2005). The Stigma Complex is another example that focuses on the multidimensional aspects of stigma, bringing attention to the system of interrelated and dynamic parts that shape health disparities (Pescosolido & Martin, 2015). A global body of literature has emerged portraying how stigma shapes adverse downstream influences on mental health, sexual behaviors, access to health services, and HIV treatment and prevention (Joint United Nations Programme on HIV/AIDS, 2014; Lane et al., 2008; Lee et al., 2016; Meyer, 2003; Mimiaga et al., 2015; Storholm et al., 2016). Such research indicates that more robust conceptualizations of HIV risk are needed to explore the holistic and intersectional nature of stigma.

Complex Systems Theory allows for recognizing and understanding the intricacy of systems that people live, work, and play in that influence one's health (Thurner et al., 2018). Complex systems focus on the elements within a system, their interactions, and **the emerging**

effect of these interactions, rather than merely exploring the relationships in isolation from one another. Complex systems involve reinforcing processes that interact with one another and create dependencies and feedback loops to different parts within the system. Using complex systems can improve HIV research by visualizing the relationships between various HIV risk factors that operate across multiple pathways and multiple domains.

While European GBMSM experience numerous risk factors for HIV, conceptual models that link the various risk factors driving HIV health inequities among European GBMSM are lacking. Conceptual models could provide much-needed guidance for intervention development and future research. Moreover, stigma's role in creating and driving these pathways remains unclear. For this dissertation aim (Aim one: To develop a conceptual model and visualization of HIV risk that reflects stigma's role in the epidemic among European GBMSM using Complex Systems Theory), I conducted a systematic review of European HIV research and used Complex Systems Theory to develop a conceptual model that explores stigma's influence on HIV risk. I posit that diverse risk factors, arising from stigmatizing contexts, will interact with one another to shape the environment in ways that leads to HIV risk. The complex systems visualization explores the elements within the system, the interaction of factors, and *the emerging effect of these interactions* (i.e., HIV risk is (re)produced by the system) that perpetuate HIV risk and diagnosis among European GBMSM.

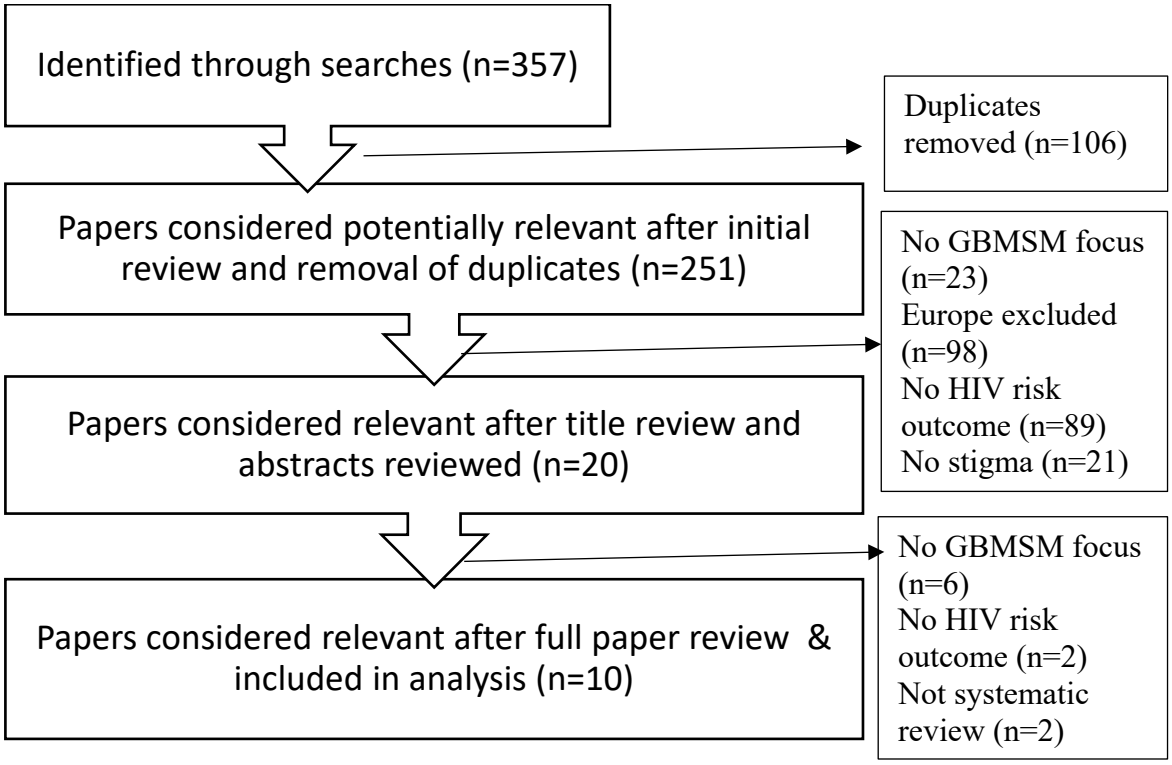
Methods

I conducted a systematic review that aligned with the PRISMA criteria (Moher et al., 2009). Inclusion criteria for publications were: (1) had HIV risk or infection as an outcome; (2) provided quantitative estimates or qualitative thematic outputs associated with HIV risk or diagnosis; (3) explored the direct and indirect role of stigma as related to HIV risk and diagnosis; (4) included

European countries (both Europe-specific publications and global reviews that included European countries); (5) included GBMSM as a focus population; (6) were peer-reviewed papers; and (7) written in English. For the purposes of this study, I defined Europe by using the World Health Organizational Regional Office for Europe classifications, which includes Central Asia (World Health Organization, 2021).

Two different groups of search terms were used. The first group of terms was "HIV" and "risk" and "Europe" and "systematic reviews" to identify systematic reviews. I searched in Web of Science, ProQuest, and Pubmed. For the systematic review articles, I identified 357 studies and 106 duplicates removed, leaving 251 for title/abstract review. I included ten systematic reviews after removing studies that did not meet the inclusion criteria as outline in Figure 2.

Figure 2. Flow chart of the systematic review of systematic reviews



The other group of search terms used for the non-systematic review studies were "HIV" and "risk" and "Europe" and "stigma" or "discrimination." I only used the Web of Science database, given that the 10 systematic review articles themselves examined over 400 research articles. For the non-systematic European articles, a total of 89 papers were found. The 15 non-systematic review studies that met inclusion criteria, but were excluded from the systematic review search, were included within this search. Nine additional studies were included that focused on Eastern Europe after reviewing studies' citations given the abundance of research from Western Europe. After combining, 44 duplicates were removed leaving 45 articles for review. After reviewing the full articles, seven did not include stigma, two did not focus on GBMSM, two were not peer-reviewed articles, and one was not available online. A total of 33 non-systematic review papers were included.

Analysis and conceptualizing HIV risk

First, I extracted the various risk factors identified in the literature and put them into Table 1. I then used those findings and categorized them according to similar themes. For example, I thematically coded condom use, the number of sexual partners, and sexual position as sexual risk behaviors. After I categorized the risk factors, I thematically analyzed them to extract the relationships and associations between the various risk factors identified. For each risk factor (e.g., sexual behaviors), I identified relationships from the literature that conceptualized specific and plausible HIV risk pathways (e.g., homonegativity <–> reduced condom use <–> increased HIV risk). The relationships identified for the visualization arose from statistically significant results from multivariate statistical models or from the major qualitative themes identified in the qualitative research. If studies found negative relationships, theoretically, in a complex system, that pathway would "turn off." The complex systems model is a dynamic system model and thus

is not meant to serve as a static visualization. I was the only coder, which may create challenges for interpretation discussed later. However, the ten systematic review articles reviewed in total 463 articles and nine out of the ten systematic review studies included two or more reviewers/coders.

I used the systems mapping software, Kumu.io, to create a visualization (Kumu, 2016). The output is a conceptual model that visually represents the HIV risk environment, which comprises the thematically extracted risk factors and their potential interrelationships, respecting the dynamic principle of complex systems (Thurner et al., 2018). Lines portray which extracted factors are directionally associated with each other. If the studies presented associations (cross-sectional), I used bidirectional arrows. I utilized unidirectional arrows when the research was causal (longitudinal). I also aimed to ensure the directionality of arrows was theoretically relevant (e.g., limited PrEP policies and financing would influence access and use of PrEP, rather than vice versa). I used text to represent the relationships between the risk factors (e.g., increased homonegativity <–> decreased condom use). I first used the analysis of the systematic reviews to connect lines among the coded risk factors. Next, I used extracted themes from the European non-systematic review articles to expand the conceptual model. The conceptual model's goal is to visualize the diverse factors that systematically pattern HIV risk among European GBMSM, with particular attention paid to the system's dynamic nature. Table 1 presents each reviewed study's results, the thematic summaries of each study's findings, and risk of bias, by examining threats to internal and external validity. The objective of this aim was to conceptualize the holistic and interactional nature of HIV risk.

Results

Table 2 identifies the major themes and subthemes from the review of all the articles and presents the major relationships between risk factors.

Table 1. Matrix of main results and thematic summaries of systematic and non-systematic review studies

Title	First author	Year	Population	Geography	Main findings	Risk of bias & strengths	Thematic summary
Systematic review studies							
Elevated risk for HIV infection among men who have sex with men in low- and middle-income countries 2000-2006: A systematic review	Baral et al.	2007	GBMSM	83 global articles 38 countries represented 12 European studies included	• GBMSM had OR=19.3 (95% CI 18.8-19.8) of HIV than general populations. • Very low prevalence countries had the highest OR of HIV infection among GBMSM [OR=58.4, 95% CI (56.3, 60.6)], as compared to low prevalence [OR=14.4, 95% CI (13.8, 14.9)] and high prevalence countries [OR=9.6, 95% CI (8.9, 10.2)]. • Low-income countries had lower OR for HIV among GBMSM [OR=7.8, 95% CI (7.2, 8.40] than middle income countries [OR=23.4, 95% CI (22.8, 24.0)].	• Four databases searched, PubMed, EMBASE, EBSCO, and the Cochrane Database of Systematic Reviews. • Validity improved as studies with less than n=50 were excluded. • Two-person coding system • Included a meta-analysis with odds ratios and 95% confidence intervals using Mantel-Haenszel method and random-effects models. • Conducted heterogeneity testing using DerSimonian and Laird Q test to address type I error.	• GBMSM have higher odds of living with HIV as compared to the general population globally. • Low prevalence countries had higher odds of HIV infection among GBMSM. • Lower-income countries had lower odds of HIV infection as compared to higher-income countries.

						• Majority of studies included were cross-sectional. • Sensitivity analyses included to remove the estimated GBMSM population from the general population estimate of men. • Large aggregate sample of GBMSM (n=63,538).	
HIV testing within general practices in Europe: a mixed-methods systematic review	Deblonde et al.	2018	General practitioners	Europe, 29 studies included	• HIV tests offered & requested more in urban areas. • Younger general practitioners (GPs) were more likely to offer HIV tests. • GPs have limited knowledge about HIV testing guidelines. • GPs made assumptions about the risk status of patients, which hinders HIV testing. • Post-test counseling less likely to occur if an HIV-negative test result was returned.	• Mixed-methods research synthesis methods used. • PRISMA guidelines used. • PubMed, Scopus and Embase databases used. • Two authors independently screened and reviewed articles. • Used checklists for qualitative and quantitative studies to assess quality and validity. • Results grouped by findings, not qualitative or	• Healthcare providers are critical partners in improving HIV care. • Barriers exist to HIV testing among providers, including time, lack of training, and cultural humility concerns. • HIV testing is not routine within

					• Barriers to HIV testing by GPs include: o Limited time; o Perceptions of who is at risk (e.g., GBMSM, IDU); o Lack of knowledge about sexual health topics; o Cultural and language barriers (particularly with migrants); and o Lack of comfort with counseling. • Interventions with GPs, including training & simplification of testing can improve HIV testing rates.	quantitative methods. • Limited research data on non-Western European countries. • 14 studies were able to assess causality (retrospective and prospective studies).	healthcare provider practices.
Barriers to HIV testing in Europe: a systematic review	Deblonde et al.	2010	Diverse, including GBMSM	Europe, 24 studies included	• Fourteen studies noted individual-level barriers. • Six studies reported on health provider barriers. • Seven studies described structural	• PRISMA guidelines not mentioned. • PubMed and Web of Science databases used. • Two authors screened and reviewed the studies.	• Diverse issues that shape HIV testing in Europe. • Fear & stigma hamper HIV testing.

					and institutional-level barriers. • Barriers centralized in a few areas, including: o Fears and worries of HIV diagnoses & disclosure; o Accessibility issues with health services; o Reluctance to offer HIV testing by healthcare providers due to lack of comfort & training; and o Policy restrictions (e.g., sex work, drug criminalization, prisons). • Limited national regulations and guidance on HIV testing.	• Three studies were able to assess causality. • Majority of studies were cross-sectional. • Small number of studies outside of Western European nations.	• Healthcare services accessibility & quality concerns hinder HIV testing. • Policies & guidelines also serve to reduce HIV testing.
Which Psychological Factors are Related to HIV	Evangeli et al.	2016	Diverse, included GBMSM	62 global articles, 5 European studies included	• Perceived benefits of HIV testing supported testing behavior. • Perceived barriers, including limited knowledge of testing	• Only quantitative studies included. • PRISMA guidelines used. • PubMed, PsycINFO, Web of Science, and the	• Diverse psychological correlates that relate to HIV testing. • Perceived benefits &

Testing? A Quantitative Systematic Review of Global Studies					sites, were associated with less testing. • Fear of testing & infection was negatively associated with HIV testing. • Knowledge about HIV was positively associated with HIV testing. • Perceived risk of HIV was associated with HIV testing. • Mixed results for discrimination and anticipated stigma and their relationships to HIV testing. • Prejudicial attitudes towards PLHIV were associated with lower uptake of testing. • Homosexuality related stigma negatively associated with HIV testing.	Cochrane Library databases used. • Two authors screened and reviewed the studies. • Meta-analyses calculations conducted if a minimum of 15 studies assessed the same relationships. • Random effect models used. • Cochran's Q test used to assess differences in study effect size and I^2 test to measure extent of inconsistency. • Rosenberg's Fail Safe N and the trim and fill method were used to validate effect sizes because smaller effect size studies are less likely to be published. • Strong interrelated reliability (Cohen's Kappa =0.85).	perceived risk of HIV was associated with testing. • Homosexuality-related stigma was associated with reduced HIV testing. • Other studies showed mixed results for discrimination & testing.

						• Six studies were able to assess causality (longitudinal). • Wide range of population characteristics included. • Challenges with estimating effect sizes due to limited studies, which hampers generalizability of the meta analyses.	
HIV Disclosure Anxiety: A Systematic Review and Theoretical Synthesis	Evangeli et al.	2017	Three studies included GBMSM 15 sampled diverse key populations 77 included both men and women	119 global articles, 8 European studies included	• Fear of discrimination and stigma were major reasons for not disclosing HIV status; 58 studies out of 119 described this phenomenon. • Anxiety about disclosure acted as barriers to ART initiation & engagement in services in 22 studies. • Mixed studies showed that HIV disclosure is	• PubMed and PsycINFO databases used. • Random 20% of articles were reviewed by two coders. • Interrater reliability (Cohen's Kappa=0.78). • Three studies were interventional studies. • Majority were cross-sectional studies.	• Stigma is a significant reason for not disclosing HIV status. • Anxiety acts as barrier to engagement with HIV services. • Mixed results for HIV disclosure & mental health.

					associated with mental health issues. • HIV disclosure concerns were associated with stigma.		
A systematic review of psychological correlates of HIV testing intention	Evangeli et al.	2018	Two studies sampled GBMSM explicitly, others included diverse populations	20 global articles, 2 European	• Strong evidence (>5 studies) found positive associations between the positive perception of benefits and HIV testing intention. • Weak positive associations identified for perceived accessibility & knowledge of testing sites and HIV testing intentions. • Strong evidence for low perceived risk of HIV being associated with non-testing intentions.	• PRISMA guidelines used. • Only incorporated quantitative studies. • PubMed, PsycINFO, Web of Science, and Cochrane Library databases used. • Two coders independently screened and extracted findings. • All but one study used a cross-sectional design.	• Perceived risks and benefits are associated with HIV testing intentions.
Understanding of Norms Regarding Sexual Practices Among	Mckechnie et al.	2013	GBMSM	16 global articles, 3 European articles included	• All papers measured subjective norms that explored expectations about sexual behavior and social influences. • Strong subjective norms were related to	• PubMed, Medline, Academic Search premier, Psychology and Behavioral Sciences Collection,	• Subjective norms influence condom use among GBMSM.

Gay Men: Literature Review					intention to use condoms ($p<0.01$). • GBMSM with strong social support had stronger social norms about condom use ($p<0.05$). • Condom use was lower among GBMSM, who reported only casual sex partners ($p<0.05$).	PsycINFO, Science Direct, Web of Knowledge and the World Health Organization's Global Health Library databases used. • Three reviewers coded and extracted information. • Selection bias of the studies reviewed given most recruited from community venues. • Five studies met the external and internal validity criteria. • Diversity in the HIV testing intentions definition across studies.	• Social support is also associated with condom use among GBMSM.
A Global Estimate of the Acceptability of Pre-exposure Prophylaxis for	Peng et al.	2018	GBMSM	68 global articles in 19 countries across six continents	• No significant publication bias was found. • Pooled PrEP acceptability 57.8% (range: 19.1-96.2). • Acceptability of PrEP is higher if provided free (46-61%),	• PubMed database used. • Two coders screened and extracted study results. • Meta analyses were performed.	• PrEP acceptance is shaped by individual-level factors such as SES. • Access to clinics was associated

HIV Among Men Who have Sex with Men: A Systematic Review and Meta-analysis					compared to 14-36% if payment was required. • GBMSM acceptability of PrEP associated with: o Perceived risk for HIV, o Received PEP before, o More education, o Higher SES, o More sex acts, o Higher # of sexual partners, and o Previously received HIV care. • The protection PrEP offers and convenience of having sex without a condom were associated with higher acceptability. • Stigma toward GBMSM was a strong barrier to PrEP uptake. • Societal stigma is also associated with reduced PrEP acceptance among GBMSM.	• Heterogeneity tests performed with Cochran Q test and I^2 statistic. • Random effects models used if high heterogeneity. • Begg and Mazumdar rank correlation used to test bias. • Subgroup analyses conducted for all moderator variables separately. • Two studies were cohort studies. • Majority of studies were cross-sectional. • Five studies were mixed methods. • High heterogeneity found in the meta-analyses despite meta regressions and subgroup analyses. • Subgroup analyses had restricted power because of low sample sizes.	with PrEP acceptability. • Cost of PrEP influenced acceptability. • Stigma hindered the acceptability of PrEP.

					• Inaccessibility of service locations was a barrier to PrEP acceptance.		
A systematic review of adherence to oral pre-exposure prophylaxis for HIV – how can we improve uptake and adherence?	Sidebottom et al.	2018	Diverse, includes 15 GBMSM studies	18 global articles 10 conference proceedings 5 European articles included	• Stigma reported in quantitative and qualitative studies as barriers to PrEP adherence. • Governmental policy factors influenced PrEP uptake. • Low perceived risk is also related to PrEP uptake. • Side effects of the medicine hampered PrEP adherence.	• Population, Intervention, Comparison, Outcome (PICO) framework used. • Ovid Medline, Web of Science, EMBASE, and Cochrane Library databases used. • One coder reviewed studies and extracted results. • 24 studies were able to assess causality (randomized control trials or open label extensions) • Challenges with adherence measures such as pill counts and electronic monitoring in reviewed studies.	• PrEP uptake and adherence are influenced by governmental policies, risk perceptions, side effects of the medicine, and stigma-related concerns.
A systematic review	Stromdahl et al.	2015	GBMSM	24 studies included	• Condom use, universal ARV coverage, TaSP, &	• Grading of Recommendations Assessment,	• The highest graded interventions

of evidence to inform HIV prevention interventions among men who have sex with men in Europe					peer outreach interventions had a high HASTE grade for preventing HIV. • Unmet condom needs existed. • Peer support reduced unprotected anal intercourse. • HASTE grade 2a interventions included voluntary counseling and testing, condom compatible lubricant, & PEP. • HASTE grade 2b interventions included individual counseling, peer-led group interventions for GBMSM living with HIV, sex club interventions, online prevention messaging & social marketing interventions & voluntary male circumcision. • HASTE grade 3 interventions included serosorting, semen avoidance,	Development, and Evaluation (GRADE) system used. • HASTE system used. • Hill's criteria for causality used in the HASTE grading system. • Population, Intervention, Comparison, Outcome (PICO) model used. • PubMed, EMBASE, Medline, Cinahl, PsycINFO, Cochrane Library and the World Health Organization publication databases used. • Two coders screened, extracted study results, and graded studies. • Limited implementation studies found in Europe.	included universal ARV coverage, TaSP, use of condoms, & peer outreach interventions. • Other lower quality interventions also exist.

					non-use of poppers, & reducing alcohol binge drinking.	• 10 of the reviewed studies included longitudinal assessments.	
Non-systematic review studies							
People with HIV in HAART-Era Russia: Transmission Risk Behavior Prevalence, Antiretroviral Medication-Taking, and Psychosocial Distress	Amirkhanian et al.	2011	PLHIV, including MSM	Russia	• 25% noted being refused healthcare. • 21% isolated from other patients at the hospital. • AIDS-related discrimination was the single predictor of condom use in the last three months β= -0.2 (p=0.012). • Depression was associated with being offered HAART but not accepting (aOR=1.05, 95% CI (1.01, 1.08)). • Discrimination was associated with not accepting HAART (aOR=1.06, 95% CI (1.01, 1.12)).	• Cross-sectional study. • Recall bias can create challenges. • Selection bias is present given recruitment strategy at clinics and NGOs. • Adjusted statistical analyses conducted.	• HIV discrimination negatively predicted condom use. • Poor mental health shapes the use of ARVs. • Discrimination was associated with not accepting ARV treatment.
Policy responses to HIV/AID	Ancker et al.	2015	Diverse, including GBMSM	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenista	• Persistent stigma hampered HIV prevention efforts in the region.	• Review of literature. • PubMed, Global Health, EMBASE,	• Stigma hampers HIV prevention efforts

S in Central Asia				n, Uzbekistan	• Social stereotyping and low levels of rights awareness resulted in stigma. • Poorly trained health professionals enacted stigma. • GBMSM hid their orientation, fearing discrimination and legal prosecution, particularly in Turkmenistan and Uzbekistan.	Web of Science, and International Bibliography of Social Sciences databases used. • Reviewed legislation. • Limited information provided about methods, screening processes, and assessment of bias.	• Low rights awareness & stereotyping result in stigma • Health professionals enact stigma • GBMSM hide sexual orientation due to stigma
Structural and environmental factors are associated with internalized homonegativity in men who have sex with men: Findings from the European	Berg et al.	2013	GBMSM	Europe	• Laws recognizing same-sex relationships and same-sex adoption were associated with reduced internalized homonegativity [β= -0.709 95% CI (0.775 to 0.392) & β= -0.394 95% CI (0.730-0.107), respectively]. • Community-level factors, such as not wanting homosexuals as neighbors, were associated with higher homonegativity	• Cross-sectional survey. • Used 235 transnational websites and NGOs for recruitment. • Selection bias is of concern given online survey and convenience sampling. • Recall and self-report biases are a concern. • Adjusted statistical analyses included. • Explored macro-, meso-, and micro-	• Laws that recognize same-sex marriage and adoption reduce internalized homonegativity. • Community-level stigma was associated with higher homonegativity. • Individual-level factors such as

GBMSM Internet Survey (EMIS) in 38 countries					[β=0.610, 95% (0.006, 0.015). • Individual-level factors, such as: o Exposure to violence [β= -0.029, 95% CI (-0.011, -0.008)], o HIV/STI information [β= -0.099, 95% CI (-0.344, -0.308)], o accessing HIV testing β= -0.073, 95% CI (-0.320, -0.267)], o STI testing β= -0.068, 95% CI (-0.255, -0.209)], and, o access to condoms (β= -0.033 95% CI (-0.117, -0.084)] were all negatively associated with homonegativity.	levels of associations. • Small proportion of respondents from Eastern Europe. • Geographically diverse. • Large sample size of almost 180,000 GBMSM.	knowledge, use of HIV & STI testing, and condom access are associated with lower stigma.
The Challenges of Transition From	Gotsadze et al.	2019	Diverse, including GBMSM	• Eastern Europe • Central Asia	• Political contexts shaped responses to health.	• Used a Transition Preparedness Assessment of the Global Fund.	• Political contexts were a vital theme that arose.

Donor-Funded Programs: Results From a Theory-Driven Multi-Country Comparative Case Study of Programs in Eastern Europe and Central Asia Supported by the Global Fund					• GDP influenced the ability to spend on healthcare. • Laws related to key populations, such as criminalization, influenced HIV service efforts. • Countries in the region are dependent on donors for HIV financing. • Specific programs such as harm reduction are solely dependent on donor funds. • Non-governmental and civil society organizations are critical service providers for key populations. • Country Coordinating Mechanisms are important, yet post-Global fund may be a challenge to continue. • Limited absorption of HIV medical training. • Poor healthcare service quality & human resources.	• Cross sectional study. • Mixed methods approach. • Reviewed quantitative data from public sources, such as the World Bank, WHO, UNAIDS. • Qualitative data gathered through in-depth interviews with key stakeholders. • Desk review of policies, evaluations, and program performance and expenditure reports conducted. • Triangulation of findings across data types performed.	• The political contexts shape responses and laws regarding key populations • Funding influences HIV services and access to ARVs. • Low-quality healthcare services.

					• Higher prices for ARV medications. • Low quality of local pharmaceutical medication supplies. • Interrupted supply of ARV medications. • Limited HIV surveillance systems.		
Never tested for HIV in Latin-American migrants and Spaniards: prevalence and perceived barriers	Hoyos et al.	2013	Diverse, 29% were GBMSM	Spain	• Fear of discrimination or rejection was less than 2% of the 2,455-person sample. • Low-risk perceptions of HIV risk. • Concerns about the loss of anonymity reduced testing.	• Cross-sectional study. • Included HIV testing in a mobile unit. • Selection bias is a concern given convenience sample. • Limited time at testing site hindered data collection with the survey. • Recall bias is a concern. • Adjusted statistical analyses performed.	• Risk perceptions and concerns about confidentiality are associated reasons for not testing.
Sexual identity, stigma, and depression: the role of	Hylton et al.	2017	GBMSM	Russia	• Depression was higher among GBMSM identifying as bisexual [AOR=0.71, 95% CI (0.52-0.97)].	• Cross-sectional study. • Selection bias is a concern given use of respondent driven sampling used to recruit	• Experiencing stigma was associated with higher depression. • Homonegativity associated

the "anti-gay propaganda law" in mental health among men who have sex with men in Moscow, Russia					• GBMSM who reported experiencing stigma in the last 12 months had higher odds of depression [AOR=1.75, 95% CI (1.20-2.56)]. • GBMSM, who reported discomfort with their identity (internalized homonegativity) had higher odds of depression [AOR=5.85, 95% CI (2.71, 12.64). • History of incarceration increased odds of depression [AOR=1.78, 95% CI (1.00-3.17)]. • Odds of depression were higher among GBMSM surveyed after the St. Petersburg anti-gay ordinance [AOR=1.65, 95% CI (1.23-2.22)]. • The interaction of experiencing stigma and the anti-gay	"hard to reach" GBMSM. • Recall bias is a concern. • Adjusted statistical analyses conducted. • Furnival-Wilson leaps-and-bounds used for variable selection. • Akaike's information criteria was used to select best model fits. • Assessed depression among participants before and after enactment of anti-gay ordinance.	with higher depression • Anti-gay laws have a direct relationship with increasing depression. • Anti-gay laws interact experiencing stigma to shape depression

					propaganda ordinance increased the odds of depression [AOR=2.24, 95% CI (1.49-3.39)].		
Correlates of Serosorting and Knowledge of Sexual Partner's HIV Status Among Men Who have Sex with Men in Ukraine	Iakunchykova et al.	2018	GBMSM	Ukraine	• Numerous factors were related to reduced prevalence ratio of knowledge of a partner's HIV status: o HIV positive status [APR=0.78, 95% CI (0.69-0.87)] ; o Cohabitation with male partner [APR=1.16, 95% CI (1.11-1.21)]; o College education [APR=1.07, 95% CI (1.03-1.11)]; o Sex partners identified by friends [APR=0.93, 95% CI (0.89-0.97)]; o Use of apps for sex partners [APR=0.90, 95% CI (0.86-0.03)]; o Casual or commercial sex	• Cross-sectional study. • Selection bias is a concern given use of respondent-driven sampling. • Recall bias is a concern. • Adjusted statistical analyses conducted. • AIC was used to determine best model. • Goodness of fit tests conducted to verify model. • RDS sampling weights were not used in the analyses.	• Various factors are related to knowledge of sexual partner's HIV status, mostly at the individual level. • Casual or finding sex through apps and friends reduced knowledge of HIV status. • PLHIV had a reduced probability of knowing sex partner's HIV status. • These issues challenge the ability to use

					partners [APR=0.26, 95% CI (0.0.24-0.29) & APR=0.50, 95% CI (0.42-0.60), respectively];
					o No HIV test [APR=1.38, 95% CI (1.30-1.46)];
					o Insertive sexual role [APR=1.05, 95% CI (1.01-1.09)]; and
					o Receptive sexual role [APR=1.06, 95% CI (1.01-1.11)]
					• Numerous factors related to successful serosorting (>1 means serosorting is successful):
					o HIV positive status [APR=3.80, 95% CI (2.30-4.11)] ;
					o Married to a woman [APR=0.60, 95% CI (0.39-0.92)];
					o Homosexual identity [APR=1.85, 95% CI (1.54-2.23)];
							seroadaptation to prevent HIV successfully.

					○ College education [APR=0.77, 95% CI (0.67-0.89)]; ○ Alcohol use once a week [APR=2.17, 95% CI (1.87-2.51)]; ○ Sex partners identified by friends [APR=1.27, 95% CI (1.09-1.47)]; ○ Sex partners identified by apps [APR=0.76, 95% CI (0.66-0.89)]; ○ Casual or commercial sex partners [APR=2.12, 95% CI (1.82-2.49) & APR=0.70, 95% CI (0.43-1.14)], respectively]; ○ No HIV test [APR=0.48, 95% CI (0.41-0.54)]; ○ Insertive sexual role [APR=0.62, 95% CI (0.52-0.75)]; ○ Receptive sexual role [APR=0.76,		

					95% CI (0.56-1.02)]; ○ Client of an NGO [APR=0.44, 95% CI (0.36-0.54)]; ○ No HIV test [APR=1.38, 95% CI (1.30-1.46)]; ○ Insertive sexual role [APR=1.05, 95% CI (1.01-1.09)]; and ○ Receptive sexual role [APR=0.44, 95% CI (0.36-0.54)]		
Programmes, resources, and needs of HIV-prevention non-governmental organizations (NGOs) in Africa, Central/Eastern Europe	Kelly et al.	2006	Diverse, including GBMSM	75 NGO directors, globally; 25 European NGO directors included	• NGOs had small budgets, and the paucity was even higher in Central & Eastern Europe. • Limited human resources at the NGOs. • Financing is highly dependent on foreign donors. • Specific targeted services to key populations. • NGOs provided vital services related to HIV/AIDS.	• Identified NGOs to interview via review of conference proceedings, directories, lists of NGOs in regional networks. • 99% response rate for interviews with NGO directors. • Total of 75 interviews completed. • Only the largest NGO per country interviewed	• Structural factors influence HIV/AIDS service provision efforts. • Limited financing and political will hamper HIV/AIDS prevention efforts. • AIDS-related stigma and discriminatio

and Central Asia, Latin America and the Caribbean					• Limited funding hampers HIV/AIDS efforts of NGOs. • Little political will or opposition to HIV prevention work cited as barriers among NGOs. • Stigma was reported as a major barrier to work by NGO directors. • Opposition or discomfort discussing sexuality was a frequently discussed barrier.	creating selection bias. • Scale and scope of interventions and services were difficult to determine.	n also acted as barriers.
A socioecological measurement of homophobia for all countries and its public health impact	Lamontagne et al.	2018	GBMSM	Global, including Europe	• Homophobic Climate Index, α=0.82. • Regression sensitivity confirmed a reliable and valid index. • 10%-point change in GDP per capita associated with a 1%-point reduction in the index. • Gender inequality in parliament is associated with higher homophobia. • Having more GBMSM among the	• Diverse data sources used to develop the database, including IMF economic data, Human Development Report, UNAIDS, World Values Survey, and the International, Gay, Bisexual, Trans and Intersex Association, Gallup World Poll, and	• Structural factors such as low GDP are associated with homophobia. • Homophobia is associated with reduced life expectancy and higher AIDS deaths.

					populations is associated with reduced homophobia. • 10%-point reduction in public health expenditures of GDP is associated with a 9% increase in homophobia. • AIDS deaths among men living with HIV are associated with homophobia. • 1.7-year reduction in life expectancy among men for every 10% increase in homophobia.	World Justice Project. • Challenges with reliable measures of stigma and discrimination by country. • Confirmatory factor analyses used for index development. • Adjusted statistical analyses conducted.	
The Role of Gay-Related Stigma in HIV-Risk Behavior Among Sexual Minority Men in Europe	Lelutiu-Weinberger et al.	2019	GBMSM	Europe	• Stigma was associated with risk outcomes. • A one standard deviation increase in stigma experiences was associated with increased the odds of sex under the influence of alcohol by 19%. • One standard deviation increase in stigma experiences is associated with	• Cross-sectional study. • Time-location randomized sampling used to improve heterogeneity of sample. • Recall bias is a concern given self-administered survey. • Adjusted statistical analyses conducted.	• Stigma is an associated factor that increases sex while under the influence of drugs and alcohol. • Stigma is also associated with increased odds of sex

					increased odds of sex under the influence of cannabis by 27%. • One standard deviation increase in stigma experiences is associated with increased odds of sex under the influence of drugs by 49%. • One standard deviation increase in stigma experiences is associated with increased odds of condomless sex with a casual partner by 11%. • One standard deviation increase in stigma experiences is associated with increased odds of knowing where to HIV test but not testing.	• Level-2 models would not converge. • Sensitivity analyses conducted to improve validity of interpretation for models with missing data.	without a condom.
Men who have sex with men in Southeastern Europe:	Longfield et al.	2007	GBMSM	Southeast Europe	• Fifty-one men participated in in-depth interviews. • "Cleanliness" is believed to indicate no HIV or STIs—those that are	• Cross-sectional study. • Sampling was completed via interviewers' social networks.	• Diversity of sexual practices, such as non-condom use, cruising, exchange of

Underground and at increased risk for HIV/STIs					wealthy, attractive, and not of Roma or Albanian descent. • Younger GBMSM exchanged sex for money or goods with older GBMSM. • One-night stands were the most commonly discussed relationship types. • Cruising and online were the primary sources of sexual partner seeking. • Difficulty in maintaining same-gender relationships, lots of GBMSM identified as "straight." • Half of the interviewees reported having four more sexual partners a month. • Concerns raised about having safe places for sex given concerns about stigma and safety. • View "others" as a predominant group	• Multiple coders of qualitative data included. • Recall and information bias are a concern. • Improved training of interviewers needed given variability of notes.	sex for money exist. • Low HIV risk perceptions. • Belief that "others" have HIV & STIs more (e.g., Roma) • Most GBMSM did not discuss HIV & STI testing. • Concerns about confidentiality and discrimination reduce the use of HIV & STI services.

					living with HIV—not within social networks. • Low perceived risk of HIV. • Use of condoms was described, although non-condom use was also prevalent. • Treatment of STIs and HIV is low because of healthcare discrimination.		
HIV Stigma and Unhealthy Alcohol Use Among People Living with HIV in Russia	Lunze et al.	2017	PLHIV	Russia	• Longitudinal adjusted analyses indicated HIV stigma score was β=0.60 (95% CI 0.03, 1.17) points higher among those with alcohol dependence vs. not. • Severe depression β=1.86 (95% CI 1.23, 2.49) associated with higher stigma score. • Low social support β=0.67 (95% CI 0.10, 1.24) is associated with a higher stigma score. • Persons with alcohol dependence had a personalized stigma	• Pre-post observational intervention study. • Selection bias is a concern because participants sampled from health clinics. • Adjusted statistical analyses conducted. • Recall is a concern. • 30% of participants had missed follow-up visits created more challenges for interpretation.	• HIV stigma is related to alcohol use and dependence. • Depression is associated with higher stigma. • Low social support is associated with higher stigma.

					score that was 0.34 higher (95% CI 0.11-0.57). • No relationship between risk, alcohol use, and any measure of HIV-related stigma.		
Pre-exposure prophylaxis to prevent the acquisition of HIV-1 infection (PROUD): Effectiveness results from the pilot phase of a pragmatic open-label randomized trial	McCormack et al.	2016	GBMSM	U.K.	• Of the 544 GBMSM participants (275 in the immediate group (PrEP), 269 in the deferred group), there was 259 patient-years of follow-up in the immediate group versus 222 (90%) of 245 patient-years in the deferred group. • Three HIV infections occurred in the immediate group (1·2/100 person-years) versus 20 in the deferred group (9·0/100 person-years). • The relative reduction of the immediate group vs. deferred was 86%, 90% CI 64–96.	• Cohort study. • Randomized immediate vs. deferred pragmatic design. • Powered to detect a 50% reduction in HIV incidence with a sample size of 5,000. • Final sample size was 500. • Intent to treat analyses used. • Low completion of monthly questionnaire to test longitudinal sexual behaviors. • No adjusted statistical analyses. • Trial stopped early which increases Type I error.	• PrEP reduces high risk in a longitudinal study.

					• Use of immediate PrEP vs. deferred PrEP reduced the risk of HIV infection among U.K. GBMSM.	• Access of PrEP outside the study may also be a concern.	
On-demand preexposure prophylaxis in men at high risk for HIV-1 infection	Molina et al.	2015	GBMSM	France	• Of the 400 (199 treatment, 201 control) included GBMSM over a median of 9.3 months (interquartile range, 4.9 to 20.6). • A total of 16 HIV infections occurred during follow-up. • Two infections happened in the treatment (TDF-FTC group) (incidence, 0.91 per 100 person-years) and 14 in the control group (incidence, 6.60 per 100 person-years). • The relative reduction for the TDF-FTC treatment group was 86% (95% confidence interval, 40 to 98; P = 0.002). • Use of PrEP before and after sexual	• Cohort study. • Randomized PrEP vs. placebo design. • Sample size calculation indicated 1,900 participants needed, a total of 445 were screened. • Intent to treat analyses. • No adjusted statistical analyses. • Self-report and recall bias for adherence.	• On-demand PrEP reduces the risk of HIV infection.

					activity reduced HIV infections by 86%.		

Provider-Initiated HIV Testing for Migrants in Spain: A Qualitative Study with Health Care Workers and Foreign-Born Sexual Minorities	Navaza et al.	2016	GBMSM & health providers	Spain	• Provider-initiated HIV testing is perceived positively.
					• "Holes" existed within the health system, as described by providers, regarding linkage to HIV care and confidentiality.
					• GBMSM concerned about social repercussions and HIV status.
					  ○ Non-citizen GBMSM feared being removed from the country.
					  ○ GBMSM expressed fear of increased social security contributions if status shared across government.
					• Migrant GBMSM described local GBMSM as "bad," which is rooted in
						• Cross-sectional study.
						• Qualitative study.
						• One coder coded and analyzed data.
						• Multiple interview guides used based on participant.
						• Data saturation not reached.
						• Selection bias of participants is a concern.
							• Stigma exists among migrant GBMSM about "sexually liberal" local GBMSM in Spain.
							• Issues with linkage to HIV care and confidentiality exist.
							• Concerns about stigmatizing repercussions of HIV diagnoses.

					stigma against the "sexually liberal" behaviors. • GBMSM described discrimination with health providers because of migrant status and living with HIV.		
HIV-related discrimination in European health care settings	Nostlinger et al.	2014	PLHIV	Europe, 14 countries	• Majority of respondents who were diagnosed with HIV were infected via sexual transmission. • 32% reported HIV-related discrimination. • Higher reports of discrimination by healthcare providers in Austria, Poland, and Greece. • Self-reported discrimination by a healthcare provider was associated with the patient not being "open" to discuss sexual health and • Those who felt that they have been pressured, forced, or	• Cross-sectional study. • Recall bias is a concern given self-administered survey. • Selection bias is a concern as recruited from HIV treatment centers and community-based HIV organizations. • Adjusted statistical analyses. • Low sample size of participants from certain countries.	• Challenges with meeting sexual health needs in health care settings. • Higher levels of discrimination were associated with lower quality of healthcare. • PLHIV in certain countries, Austria, Greece & Poland, reported more discrimination.

					intimidated into sexual activities experienced lower quality care.		
Anti-LGBT and Anti-immigrant Structural Stigma: An Intersectional Analysis of Sexual Minority Men's HIV Risk When Migrating to or Within Europe	Pachankis et al.	2017	GBMSM	Europe	• Anti-gay structural stigma was associated with higher odds of inadequate HIV prevention coverage, lack of use, and lack of disclosure of sexuality during HIV testing. • Migrant GBMSM living in anti-immigrant receiving countries had a reduced odds of sexuality disclosure during HIV test compared to migrant GBMSM living in immigration accepting countries. • Anti-gay stigma in the country from emigration was associated with higher odds of inadequate HIV prevention coverage, lack of transmission knowledge, and lack	• Cross-sectional survey. • Used 235 transnational websites and NGOs for recruitment. • Selection bias is of concern given online survey and convenience sampling. • Recall and self-report biases are a concern. • Adjusted statistical analyses included. • Small proportion of respondents from Eastern Europe. • Geographically diverse. • Adjusted multi-level statistical analyses performed. • Use of conservative correction for multiple analyses reduced significance of	• Stigma was associated with inadequate HIV services among migrant GBMSM.

					of disclosure of sexuality during testing.	association from 50% to 30%.	
Homonegativity and Associated Factors Among Men Who Have Sex with Men in Estonia	Parker et al.	2016	MSM	Estonia	• GBMSM that had fewer family members who knew about their sexual orientation had higher homonegativity scores (p=0.011). • MSM that had fewer friends who knew about their sexual orientation had higher homonegativity scores (p=0.012). • Multivariate models: homonegativity was not associated with depression, sexual behaviors such as alcohol use, unprotected sex, number of sexual partners, sex in a public venue, or drug use. • In multivariate models, persons with higher scores on the anxiety score were more likely to have had higher	• Cross-sectional study. • Recall bias is a concern. • Selection bias is a concern given convenience sample and use of organizations and social media for recruitment. • Adjusted statistical analyses included.	• Limited social support was associated with higher homonegativity. • Anxiety and homonegativity positively associated.

					homonegativity scores [aOR=1.36, 95% CI (1.07-1.74)].		
PEP and TasP Awareness among Italian MSM, PLWHA, and High-Risk Heterosexuals and Demographic, Behavioral, and Social Correlates	Prati et al.	2016	Diverse, including GBMSM	Italy	• Multivariate models showed that among GBMSM, knowledge of treatment as prevention was associated with lower levels of HIV stigma [aOR=0.56, 95% CI (0.42-0.74]). • Among GBMSM, more frequent contact with HIV/AIDS organizations associated with awareness of TaSP [aOR=1.40, 95% CI (1.20-1.64)]. • Among GBMSM, knowledge of TaSP was associated with HIV testing in the last year [aOR=1.57 95% CI (1.29, 1.90)] and master's education [aOR=1.33 95% CI (1.06, 1.66)]. • Among GBMSM, knowledge of PEP was associated with lower HIV stigma	• Cross-sectional study. • Selection bias is a concern given online convenience sample. • 25% of participants excluded due to incomplete data. • Power calculations conducted to ensure sample size was large enough at 80% power. • Adjusted statistical analyses performed.	• Knowledge about PEP and TaSP was associated with lower HIV stigma. • Age and education were associated with knowledge about TaSP and PEP.

					[aOR=0.74 95% CI (0.55, 0.99)]. • Among GBMSM, knowledge of PEP was associated with frequent contact with organizations [aOR=1.32 95% CI (1.16, 1.50)]. • Older age was associated with less knowledge about PEP. • Master's degree education was associated with higher knowledge about PEP.		
Risk of HIV transmission through condomless sex with serodifferent gay couples with the HIV-positive partner	Rodger et al.	2019	GBMSM	Europe	• Longitudinal, from 2010 to 2017, there were 76,088 reported sexual acts without a condom. • Thirty-seven percent of men reported sex without a condom with non-steady sexual partners. • Fifteen new infections occurred in the study, of which none were phylogenetically	• Observational cohort study. • Selection bias given recruitment completed at clinics. • Conducted phylogenetic testing to match HIV genetic makeup. • Sample size of 1,770 eligible couple years achieved.	• ARV treatment and undetectable viremia reduce the odds of transmission.

taking suppressive antiretroviral therapy (PARTNER): final results of a multi-center, prospective, observational study					linked to within-couple transmissions, resulting in a zero HIV transmission rate among couples.	• No adjusted statistical analyses.	
Internalized homonegativity predicts HIV-associated risk behavior in European men who have sex with men in a 38-country cross-	Ross et al.	2013	GBMSM	Europe	• Positive LGBTQ+ legal climates were associated with lower internalized homonegativity. • Being "out" and older age was also associated with lower homonegativity. • Higher internalized homonegativity was associated with: o Reduced perceived control of sexual risk-taking;	• Cross-sectional survey. • Used 235 transnational websites and NGOs for recruitment. • Selection bias is of concern given online survey and convenience sampling. • Recall and self-report biases are a concern. • Adjusted statistical analyses included.	• Lower homonegativity found in countries with more protective LGBTQ+ legal climates. • Higher homonegativity associated with reduced perceived control of sexual risk, reduced HIV

sectional study: some public health implications of homophobia					○ Reduced HIV testing; and ○ Higher frequency of sexual partners with no condoms used in the last 12 months. • Highest stepwise predictors of # of non-steady partners was homonegativity, Gini coefficient, and LGB legal climate.	• Small proportion of respondents from Eastern Europe. • Geographically diverse. • Large sample size over 180,000 participants. • Adjusted statistical analyses performed. • Small effect sizes.	testing, & increased sex without a condom. • Higher internalized homonegativity, Gini coefficients associated with reduced perceived control in sexual risk-taking. • Protective LGBTQ+ climates are associated with increased perceived control over sexual risk.
Late Presentation of HIV Infection in the Netherlands: Reasons	van Opstal et al.	2018	PLHIV, over 50% were GBMSM	Netherlands	• Qualitative interviews with 31 late presenters indicated HIV related discrimination as a major reason for presenting late for testing.	• Cross-sectional study. • Qualitative methods. • Selection bias is a concern given purposive sampling. • Data saturation occurred.	• Concerns about discrimination were related to late presentation of PLHIV. • Lack of symptoms

for Late Diagnoses and Impact on Vocational Functioning					• Lacking symptoms was also associated with late presentation for treatment. • Low-risk perceptions and limited knowledge about HIV transmission routes are related to late presentation. • Late presentation and advanced AIDS made it challenging for presenters to hide their HIV status because of being sick. • Participants stated that general practitioners should be proactive in offering HIV tests. • Fear of impact of HIV diagnoses was also a reason for late presentation.	• Recall bias is of concern given self-report. • Multiple coders coded and analyzed data. • Conducted confirmatory checks with persons that met eligibility criteria for the study (i.e., late presenters).	and low risk perceptions also influenced late presentation.
Reductions in access to HIV prevention and care services	Santos et al.	2017	GBMSM	Global, includes Europe	• 8% of GBMSM reported being arrested or convicted for being GBMSM. • 18% of GBMSM in Eastern Europe and Central Asia reported arrest or conviction.	• Cross-sectional study. • Global survey. • Selection bias is a concern given convenience sample.	• Criminalization and incarceration negatively influence STI treatment

are associated with arrest and convictions in a global survey of men who have sex with men					• No significant association between arrest or conviction and access to HIV testing and treatment. • Sensitivity analyses showed that being an GBMSM with arrest or convictions in Western Europe and North America was associated with reduced access to STI treatment (aOR=0.44 95% CI 0.25,0.79) and medical care (aOR=0.41 95% CI 0.23-0.74).	• Recall bias given self-report. • Adjusted statistical analyses performed.	and medical care.
Conversation about serostatus decreases risk of acquiring HIV: results from a case control study comparing MSM	Santos-Hovener et al.	2017	GBMSM	Germany	• Cases were GBMSM who HIV tested, reported GBMSM sex, and diagnosed with HIV. • Limited knowledge and agreement with Undetectable=Unstransmittable. • Cases had more unprotected sex with unknown HIV status partners.	• Cross-sectional case-control study. • Selection bias given recruitment at HIV testing sites and convenience sample. • Adjusted statistical analyses conducted. • Small sample size of 105 cases and controls. • Comparison group included.	• PLHIV were more likely not to use condoms during sex. • Risk perceptions shape condom use. • Always using condoms and having conversations about HIV

with recent HIV infection and HIV negative controls					• Low-risk perception was associated with less condom use. • Multivariate analyses: "Always" using condoms outside of a relationship reduced the odds of being diagnosed with HIV. • Multivariate analyses: Having had conversations about HIV status before sex reduced the odds of being diagnosed with HIV.		status was associated with reduced HIV diagnoses.
Inequities in access to HIV prevention services for transgender men: results of a global survey of men who have sex with men	Scheim et al.	2016	GBMSM	Global, includes Europe	• Significant association was found between being arrested or convicted for being trans and lack of access to condoms (p=0.04). • Higher provider stigma scores were associated with less access to HIV testing (p=0.05). • Trans GBMSM had lower odds of perceived access to HIV testing	• Longitudinal global survey. • Only baseline data analyzed. • Selection bias is a concern given online, convenience and purposive sampling methods. • Recall bias is an issue given self-report. • Matched study of cis GBMSM controls to trans GBMSM.	• Criminalization due to trans identity is associated with reduced access to condoms. • Trans identity is also associated with reduced access to HIV testing and lubricants.

					[aOR=0.57, 95% CI (0.33, 0.98)] and lubricants [aOR=0.54, 95% CI 0.30, 0.98)], as compared to non-trans GBMSM	• Adjusted statistical analyses conducted. • Sensitivity analyses performed with SES and ability to meet need with current income.	
Engaging 'gay' businesses in HIV prevention 'Everywhere': Findings from a qualitative study in eight European cities	Sherriff et al.	2013	GBMSM	Europe	• Qualitative study that described GBMSM stigma against PLHIV because of lack of information. • Business owners see a role for their gay businesses to improve community knowledge and development. • In Eastern European nations, access to updated and "exciting" information is expensive for busines owners. • Desire for information in gay businesses to be non-threatening and non-offensive. • Need for educational materials particularly	• Cross-sectional study. • Qualitative study. • Selection bias is a concern given purposive sampling. • Diverse European cities included; however limited gay businesses exist in Eastern Europe. • Interview guide informed by a scoping review. • Single coder coded and analyzed data.	• Gay businesses are interested in supporting HIV prevention efforts within their countries. • Need for up to date and innovative educational materials. • Interest exists in participating in the European gay businesses Everywhere Scheme. • Free condoms and lubricants are

					focused on young GBMSM. • Business owners were interested in participating in the Everywhere Project: a European Seal of Approval in HIV prevention for gay businesses. • Need for free condom and lubricant distribution to support businesses as places of HIV prevention.		important for businesses to support HIV prevention efforts.
Until we have laws…everything is useless!': intersectionality, self-identified needs and inequity among sexual and gender minoritie	Stojanovski et al.	2019	LGBTQ+	North Macedonia	• A fear of accessing institutional services existed due to experiences of personal and vicarious stigma. • Living outside the capital city reduced access to sexual health services. • Centralization of HIV services limited access to ARVs outside the capital. • Fear of being "outed," particularly in smaller towns,	• Cross-sectional study. • Qualitative study. • Selection bias is a concern given purposive and snowball sampling. • Diverse geography included within the country. • Data saturation achieved. • Two coders coded and analyzed data.	• Concerns about stigma influence utilization of sexual health services. • Geographic isolation reduces access to sexual health services.

s in Macedonia					creates barriers to meeting sexual health needs. • Roma SGM experienced heightened violence and disparity in access to sexual health services.		
"It is one, big loneliness for me": the influences of politics and society on men who have sex with men and transwomen in Macedonia	Stojanovski et al.	2015	GBMSM & trans women	North Macedonia	• Strong distrust of government health institutions existed. • Use of health services predominately found at NGOs compared to government institutions due to perceived stigma and distrust. • Most GBMSM preferred to get sexual health services outside the government-run healthcare system. • Concerns that the government spread homophobia and stigma.	• Cross-sectional study. • Qualitative study. • Selection bias is a concern given purposive snowball, use of gay apps, and venue-based time sampling. • Two coders coded and analyzed the data. • Data saturation achieved.	• Structural concerns about how the government perpetuates stigma against GBMSM and trans women. • Use of sexual health services is predominately at the NGOs. • Distrust and fear of government institutions reduce access and utilization of government-

							sponsored sexual health services.
Non-governmental organizations and the sexual and gender minority community in North Macedonia: narratives about community practice and building	Stojanovski et al.	2020	LGBTQ+	North Macedonia	• Limited community organizing and engagement. • Community members distrusted processes and wanted more community-led work. • Desired unification and collaboration across LGBTQ+ serving organizations. • Need to build power and coalitions.	• Cross-sectional study. • Qualitative study. • Selection bias is a concern given purposive and snowball sampling. • Diverse geography included within the country. • Data saturation achieved. • Two coders coded and analyzed data.	• Need for the building of power to better meet the needs of LGBTQ+. • Limited community-engaged programming and services. • Stronger organizing can pressure the government to address LGBTQ+ needs.
The devil has entered you': a qualitative study of men who have sex	Stojisavljevic et al.	2017	GBMSM	Bosnia & Herzegovina	• GBMSM felt unequal and discriminated against by society. • Ubiquitous homophobia kept GBMSM from being "out."	• Cross-sectional study. • Qualitative study. • Selection bias is a concern given recruitment done through NGOs.	• Distrust of health providers and government institutions are prevalent.

with men and the stigma and discrimination they experience from healthcare professionals in Bosnia and Herzegovina					• GBMSM described the passive role that the State and media play as allowing for stigma to flourish. • Healthcare stigma existed, which limited the desire to access services or shaped denial of care while at the health institutions.	• Multiple coders coded and analyzed the data.	• Stigma limits the utilization of services. • Stigma hurts the ability to live authentically, including at work, getting married, etc. • Stigma creates mental health challenges.
Effects of Stigmatization on Gay Men Living with HIV/AIDS in a Central-Eastern European Context: A Qualitative Analysis	Takacs et al.	2013	GBMSM	Hungary	• Concurrent experiences of HIV and gay-related stigma are prevalent. • Most MSM concealed their sexual identities and HIV status. • Hiding one's status is used to protect against enacted stigma. • The healthcare system was a frequently described location for discrimination.	• Cross-sectional study. • Qualitative study. • Selection bias is a concern given only in Budapest, use of internet, and snowball sampling. • Three coders coded and analyzed data. • Data saturation not achieved.	• Gay and HIV-related stigma is present. • Stigma increases concealment of identities. • Stigma reduces utilization of health services. • Stigma reduces discussions of HIV status

from Hungary					• Reduced social circles seen after one's HIV diagnosis, although replaced with more PLHIV. • Sharing HIV status with other gay men or sex partners is limited due to concerns about discrimination. • Protection against HIV among PLHIV was rooted in altruism, protecting others from infection, while for negative MSM, it was related to protecting oneself. • Avoided sex with PLHIV is a regular practice.		and sharing with sexual partners and friends.
Do men who have sex with men use serosorting with casual partners in France? Results of a	Velter et al.	2019	GBMSM	France	• Serosorting was higher with 10 or less sexual partners among HIV negative GBMSM [aOR=1.5, 95% CI (1.0, 2.2)]. • Among GBMSM living with HIV, the use of the internet for partner seeking was associated with serosorting	• Serial cross-sectional study. • Selection bias a concern given the use of internet and gay websites & newspapers. • Serosorting outcome was reconstructed from data not via the survey questions.	• Serosorting happens among GBMSM in France. • Lower frequency of sexual partners was associated with higher

nationwide survey (ANRS-EN17-Presse Gay 2004)					[aOR=2.16, 95% CI (1.00, 4.67)]. • Cruising reduced the odds of serosorting both GBMSM living with HIV and not [aOR=0.28, 95% CI (0.13, 0.60) and aOR=0.59, 95% CI (0.39, 0.89), respectively].	• Adjusted statistical analyses conducted.	odds of serosorting. • Cruising is associated with reduced serosorting.
HIV self-testing intervention experiences and kit usability: results from a qualitative study among men who have sex with men in the SELHPI (Self-Testing Public Health Interventio	Witzel et al.	2020	GBMSM	England and Wales	• Qualitative interviews indicated that self-testing related to a potential sexual risk event helped prevent stigma and confidentiality concerns. • Stigma was cited as a barrier to testing at clinics. • Self-testing allowed for more comfort, reduction in anxiety, and control over the testing process. • For GBMSM who hadn't regularly tested before, the self-testing kit facilitated changes in testing behaviors.	• Randomized control trial. • Qualitative sub-study. • Purposive sampling of participants across the two study arms (control or intervention). • One coder coded and analyzed the data. • Limited data on those who tested positive, so those results are inconclusive.	• Benefits of self-testing include a reduction in stigma experiences. • The intervention with reminders and follow-up assisted with testing. • Self-testing increased testing among previously non-testers. • Self-testing was overall a positive

n) randomized controlled trial in England and Wales							experience & considered valid.

Table 2 identifies the major themes and subthemes from the review of all the articles (systematic and non-systematic reviews). The table identifies major relationships between risk factors identified from the literature.

Table 2. Themes and subthemes extracted from systematic review of articles

Thematic risk factor	**Risk factor subthemes**	**Related articles**
Stigmatizing policies shape the HIV risk environment	• Stigmatizing policies and laws, such as "anti-gay propaganda," shape poor mental health and access to sexual health services. • Policy protections are associated with less mental health issues. • Stigma can shape sexual risk behaviors.	• Ancker et al., 2015 • Berg et al., 2013 • Deblonde et al., 2010 • Gotsadze et al., 2019 • Hylton et al., 2017 • Kelly et al.., 2006 • Pachankis et al., 2017 • Ross et al., 2013 • Santos et al., 2017 • Scheim et al., 2016 • Stojanovski et al., 2015 • Stojisavljevic et al., 2017
Policies shape access to HIV and sexual health services	• Funding and guidelines for HIV testing, treatment & prevention influence access and use of services. • Health systems governance and policies shape access to services.	• Deblonde et al., 2010 • Gotsadze et al., 2019 • Kelly et al., 2006 • Peng et al., 2018 • Sherriff et al., 2013 • Sidebottom et al., 2018 • Stromdahl et al., 2015
Macroeconomics shape homophobia & HIV epidemiology	• Country income categorization influences the homophobic climate. • GBMSM in low-income countries have lower odds of HIV infection.	• Baral et al., 2007 • Kelly et al., 2006 • Lamontagne et al., 2018 • Peng et al., 2018

Stigmatizing institutional values and health care norms shape HIV services	• Accessibility issues to sexual healthcare services.
	• Acceptability issues include:
	  ○ Health provider attitudes, knowledge and clinical behaviors.
	  ○ Cultural barriers.
		• Ancker et al., 2015
		• Deblonde et al., 2010
		• Deblonde et al., 2018
		• Gotsadze et al., 2019
		• Hoyos et al., 2013

	○ Stigma, fear and distrust of institutions. • Health system's policies, regulations, and time influence sexual health services.	• Longfield et al., 2007 • Navaza et al., 2016 • Nostlinger et al., 2014 • Peng et al., 2018 • Scheim et al., 2016 • SEM van Opstal et al., 2018 • Stojanovski et al., 2015 • Stojanovski et al., 2019 • Stojisavljevic et al., 2017 • Takacs et al., 2013
Community norms and stigma influence mental health, sexual behaviors & health service usage	• Limited acceptance of gays among neighbors related to higher homonegativity. • HIV stigma is associated with depression and alcohol use. • Low social support is related to higher stigma and homonegativity. • Homophobia relates to concerns about anticipated or enacted stigma. • Internal community discrimination, e.g., PLHIV. • Societal stigmas alter perceptions and use of HIV prevention services (e.g., PrEP acceptability) and alters sexual behaviors. • Homophobia is related to more risk factors and AIDS deaths.	• Berg et al., 2013 • Evangeli et al., 2016 • Evangeli et al., 2017 • Lamontagne et al., 2018 • Longfield et al., 2007 • Lunze et al., 2017 • Navaza et al., 2016 • Parker et al., 2016 • Peng et al., 2018 • Stojanovski et al., 2019 • Stojsavljevic et al., 2017 • Stromdahl et al., 2015 • Takacs et al., 2013
Community activism & engagement can improve policies, services, & communal support	• Community development and organizing not yet strong in some countries. • Advocacy for policies, laws, & regulations taking place. • Information sharing helps with communal efforts. • Community activism can safeguard protections and services.	• Kelly et al., 2006 • Mckechni et al., 2013 • Sherriff et al., 2013 • Stojanovski et al., 2015 • Stojanovski et al., 2019 • Stojanovski et al., 2020 • Stromdahl et al., 2015

Stigma negatively influences mental health, an intermediary factor that shapes sexual behaviors	• Stigma is associated with poorer mental health. • Stigma is associated with more violence and assault against GBMSM. • Stigma can reduce social support of GBMSM, which can shape mental health and influence subjective norms. • Stigma by shaping mental health alters the use of condoms and reduces perceived control of sexual risk-taking.	• Berg et al., 2013 • Evangeli et al., 2017 • Hylton et al., 2017 • Lelutiu-Weinberger et al., 2019 • Lunze et al., 2017 • Mckechni et al., 2013 • Parker et al., 2016 • Ross et al., 2013 • Stojisavljevic et al., 2017 • Takacs et al., 2013
Stigma negatively influences sexual behavior efforts to reduce HIV infection	• Stigma reduces the use of HIV prevention services, i.e., HIV testing, PrEP use and adherence, ARVs, etc. • Stigma influences sexual behaviors such as the use of condoms. • Self-testing for HIV can disrupt stigma concerns.	• Amirkhanian et al., 2011 • Berg et al., 2013 • Deblonde et al., 2010 • Evangeli et al., 2016 • Evangeli et al., 2017 • Hylton et al., 2017 • Iakunchykova et al., 2018 • Lelutiu-Weinberger et al., 2019 • Longfield et al., 2007 • Navaza et al., 2016 • Peng et al., 2018 • Prati et al., 2016 • Santos-Hovener et al., 2017 • Sidebottom et al., 2018 • Takacs et al., 2013 • Witzel et al. 2020
Individual perceptions & behaviors influence HIV risk	• Higher frequency of sexual partners increases HIV risk. • Low condom use increases HIV. • Low-risk perceptions can increase “risky” sexual behavior. • Seroadaptation can reduce HIV risk. • Use of PrEP reduces HIV risk. • Undetectable=Untransmittable. • Risk perceptions shape HIV testing.	• Evangeli et al., 2017 • Evangeli et al., 2018 • Iakunchykova et al., 2018 • Longfield et al., 2007 • McCormack et al., 2016 • Molina et al., 2015 • Rodger et al., 2019 • Santos-Hovener et al., 2017

		• SEM van Opstal et al., 2018 • Stromdahl et al., 2015 • Velter et al., 2019
Poor mental health shapes sexual behavior to be riskier	• Depression, anxiety and internalized homonegativity shape risk perceptions and use of condoms. • Use of substances influences sexual behaviors such as less condom use. • Poor mental health influences the use of prevention services, such as ARV treatment and HIV testing.	• Berg et al., 2013 • Ancker et al., 2015 • Deblonde et al., 2010 • Evangeli et al., 2017 • Hylton et al., 2017 • Iakunchykova et al., 2018 • Kelly et al., 2006 • Longfield et al., 2007 • Lunze et al., 2017 • Ross et al., 2013 • SEM van Opstal et al., 2018 • Sherriff et al., 2013 • Takacs et al., 2,013 • Witzel et al., 2020

Sexual & health behavior prevention efforts can reduce HIV risk

Two longitudinal studies, one in the United Kingdom and another in France, both showed that the utilization of PrEP helps reduce HIV risk (McCormack et al., 2016; Molina et al., 2015; Peng et al., 2018). Another multi-center longitudinal study, which included Europe, showed that for persons living with HIV (PLHIV), the use of HIV treatment suppresses viral load, and sexual partners with undetectable viremia do not transmit HIV (Rodger et al., 2019). Condom use also supports prevention, however, one systematic review, that included three European studies, found that subjective norms among GBMSM influenced intentions to use condoms (McKechnie et al., 2013). A study by Velter et al. in France indicated that serosorting (decisions to use condoms or not during sex) varied (Velter et al., 2019). Among French GBMSM with ten or fewer sexual partners there was more serosorting, while cruising reduced the odds of serosorting (Velter et al., 2019). French GBMSM living with HIV who used the internet to find sexual partners were also

more likely to serosort (Velter et al., 2019). A systematic review of 22 countries, including two in Europe, found a positive association between perceived benefits of testing with HIV testing intention (Evangeli et al., 2018). While important, these individual behaviors and decisions (which are not all encompassing) can be shaped by other factors, such as mental health.

Individual mental health influences HIV risk

The studies identified that individual mental health issues could hinder European GBMSM's ability to use sexual health services and participate in risk-reducing behaviors. Eleven studies in the review supported findings showing that mental health alters sexual health behaviors (Ancker & Rechel, 2015; Deblonde et al., 2010; Evangeli & Wroe, 2017; Hylton et al., 2017; Iakunchykova et al., 2018; Kelly et al., 2006; Longfield et al., 2007; Lunze et al., 2017; Ross et al., 2013; Takács et al., 2013; van Opstal et al., 2018). In a study with GBMSM in Russia, depression was associated with being offered ARV treatment but not accepting it (Amirkhanian et al., 2011). In a systematic review that included eight European studies among 83 studies, anxiety about HIV status disclosure acted as a barrier to ART initiation or adherence (Evangeli & Wroe, 2017). Across 38 European countries, higher homonegativity among GBMSM was associated with reduced HIV and STI testing and reduced likelihood of seeing their physicians (Ross et al., 2013). In another study, higher homonegativity was associated with reduced condom usage and reduced perceived control over sexual risk behaviors (Ross et al., 2013). As described, mental health issues were consistently identified as influencing factors that can socially pattern HIV risk among European GBMSM. However, the mental health risk factors are themselves socially patterned by stigma.

Stigma influences mental health

The review of studies found that experiences of stigma and discrimination are related to

mental and behavioral health issues (Berg et al., 2013; Lelutiu-Weinberger et al., 2019; Lunze et al., 2017; Parker et al., 2016). A cross-European analysis of GBMSM in 38 countries indicated that men who experienced gay-related hostility and violence had increased internalized homonegativity (Berg et al., 2013). In the same study, GBMSM living in countries with laws recognizing same-sex marriage and adoptions had lower internalized homonegativity (Berg et al., 2013). In another 38 European country study, positive LGBTQ+ legal climates were associated with reduced internalized homonegativity, as was being "out" (Ross et al., 2013).

The review of studies also found that issues of stigma and discrimination were particularly salient in Eastern Europe (Hylton et al., 2017; Lunze et al., 2017; Stojanovski et al., 2019; Stojisavljevic et al., 2017; Takács et al., 2013). In Estonia, not being out was associated with higher homonegativity scores (Parker et al., 2016). In Russia, GBMSM who regularly experienced stigma within the last 12 months had higher levels of depression (Hylton et al., 2017). Similarly, those who reported discomfort with their sexual identity had higher odds of depression (Hylton et al., 2017). Lastly, the interaction of experiencing stigma and the anti-gay propaganda law elevated the odds of depression (Hylton et al., 2017). The fear of living with HIV also creates additional mental health issues, such as hiding one's serostatus (Lelutiu-Weinberger et al., 2019; Lunze et al., 2017). Other studies have similarly found that minority stressors influence being "out" and one's mental health (Stojanovski et al., 2015; Stojanovski et al., 2019). As shown, stigma is a concern across Europe, and it can serve to alter GBMSM's mental health in ways that elevate the social patterning of risk behaviors and ultimately HIV diagnosis.

Stigma influences behavioral efforts to reduce HIV infection

In addition to shaping mental health, a risk factor for HIV, the review of studies, uncovered that stigma may also reduce prevention strategies' benefits. Seroadaptation, which are decisions

about who to have sex with, the use of condoms, and sexual position, is a group of sexual behaviors that GBMSM engage in based on discussions and presumed HIV status of sexual partners. Sexual partner's HIV status influences decisions about whom to have sex with, sexual position preferences (top, bottom, versatile), and use of condoms. In a French study, serosorting is a prevention strategy utilized by GBMSM, and it was higher among GBMSM who had a lower frequency of sexual partners (Velter et al., 2019). In a Ukrainian study, Iakunchykova et al. found that among 8,100 GBMSM recruited, 13% of MSM failed at serosorting (incorrectly presumed partner status), and only 43% knew the HIV status of their last sexual partner (Iakunchykova et al., 2018). Studies in the review showed that concerns about discriminatory experiences were related to reduced HIV testing, particularly in high stigma contexts (Lelutiu-Weinberger et al., 2019; Longfield et al., 2007; Witzel et al., 2020). A systematic review study found that homosexuality-related stigma was associated with reduced HIV testing (Evangeli et al., 2016). The review of studies' findings suggests that stigma may hinder seroadaptation's utility in stigmatizing contexts given that it relies on HIV testing efforts to correctly serosort.

In the review of studies, stigma was found to shape other processes that lead to heightened HIV risk. In a 38 European country study, interpersonal stigma was associated with higher homonegativity, and higher homonegativity was associated with reduced use of condoms and perceived control over sexual risk-taking (Berg et al., 2013; Ross et al., 2013). Other studies indicated that stigma also influences adherence to prevention and ARV treatment (Amirkhanian et al., 2011; Hylton et al., 2017; Peng et al., 2018; Prati et al., 2016). In an Italian study, GBMSM's knowledge of HIV treatment and prevention was associated with lower levels of HIV stigma (Sigona, 2012). In a global PrEP acceptability study, the authors found that stigma toward GBMSM was a substantial barrier to PrEP uptake and acceptance (Peng et al., 2018). Another

European-wide study found that more stigmatizing experiences increased the odds of sex under the influence of alcohol by 19%, increased the odds of sex under the influence of cannabis by 27%, increased the odds of sex under the influence of other drugs by 49%, and increased the odds of condomless sex with a casual partner by 11% (Lelutiu-Weinberger et al., 2019). The multitude of relationships outlined from the studies serves to further portray how stigma has a role in shaping health behaviors and other intermediary factors, such as mental health, that socially pattern HIV risk among GBMSM.

Community norms and stigma alter mental health, sexual behaviors & health service usage

While already complex, the review of studies indicated that additional community factors can shape HIV risk and diagnosis. Studies' findings revealed that GBMSM's stigmatizing and discriminatory experiences relate to other risk factors within the HIV risk environment. Community psychological processes, such as fear of discrimination and distrust of health institutions, were present in the studies and created barriers to HIV prevention. In a systematic review of barriers to HIV testing in Europe, fears and worries about status disclosure arose as a central theme that produced barriers to HIV testing (Deblonde et al., 2010). In another systematic review that included eight European countries, fear of discrimination and stigma were significant reasons for not disclosing HIV status (Evangeli & Wroe, 2017). In the same study, anxiety about HIV status disclosure acted as a barrier to ARV treatment initiation (Evangeli & Wroe, 2017). In a study in Spain, concerns about the stigmatizing repercussions of HIV diagnoses shaped GBMSM migrants' use of services (Navaza et al., 2016). In North Macedonia, two qualitative studies describe stigma as a barrier to accessing health services, particularly at government institutions (Stojanovski et al., 2015; Stojanovski et al., 2019). Similar relationships between stigma and the use of services were described in other studies reviewed (Lamontagne et al., 2018; Peng et al.,

2018; Sidebottom et al., 2018; Stojisavljevic et al., 2017). The review of studies indicated that stigma and fear may create processes that hinder access to HIV testing and services.

Internal community discrimination may also influence one's risk of HIV by exacerbating experiences of stigma. For example, in a Hungarian study, GBMSM reported that their social circles (support) shrank after being diagnosed with HIV (Takács et al., 2013). However, Hungarian GBMSM increased the number of PLHIV in their social circles, which could provide additional social support. In another study, Estonian GBMSM with little or no family and friends who knew about their orientation had elevated internalized homonegativity (Parker et al., 2016). A study among GBMSM migrants in Spain found that migrant GBMSM believed local Spanish GBMSM to be too "sexually liberal" (Navaza et al., 2016). In a Southeastern Europe study, GBMSM expressed beliefs that "others," such as Albanians and Roma, were believed to be "unclean" and more likely to have HIV, further perpetuating stigma (Longfield et al., 2007). A study among PLHIV in Russia indicated that low social support was associated with higher stigma (Lunze et al., 2017). As identified in the research, a plethora of community-related factors influenced direct (sexual behaviors and HIV testing) and indirect risk factors (mental health, social support) for HIV. The studies reviewed provided additional insights for how community-level factors, such as social support or lack thereof, may socially pattern HIV among European GBMSM.

Community support & activism influences behaviors, services & policies

Community activism and organizing can also serve to improve the living conditions of GBMSM and reduce their risk of HIV. The review of studies indicated that community members have developed community coping strategies, such as sharing information about hostile health professionals and letting "new" members of the group know about which organizations they can get services from, etc. (Stojanovski et al., 2018, 2020). The LGBTQ+ community in North

Macedonia conducted activism campaigns and participated in high-level ministerial meetings, which ensured the government would safeguard HIV treatment, and prevention funds were available to address the loss of Global Fund for Tuberculosis, Malaria, and HIV/AIDS funding (Stojanovski et al., 2020). Research with gay businesses in eight European cities found that businesses were supportive of HIV prevention efforts, such as providing condoms, lubricant, and HIV information (Sherriff et al., 2011). Another study described that NGOs and civil society are essential service providers for HIV in Eastern Europe and Central Asia (Gotsadze et al., 2019). A literature review by Mckechnie et al. indicated that social support was associated with condom use among GBMSM (McKechnie et al., 2013). Lastly, a review of 24 European studies indicated that peer outreach interventions had a good Highest Attainable Standard of Evidence (HASTE) grade that supports HIV prevention (Strömdahl et al., 2015).

While community organizing and support are critical levers for HIV prevention, stigma can create barriers. Interviews with 75 NGO directors, of which 25 were in Europe, noted that stigma interferes with their provision of services (Kelly et al., 2006). In the same study, 50% of NGO directors in the former Soviet Union countries stated that lack of government political will hinders HIV work (Kelly et al., 2006). The findings from the review of studies indicated that community-based services and organizing are important factors that can influence HIV risk among European GBMSM. As elaborated, community relationships and organizing can help to improve HIV prevention efforts that would reduce GBMSM's risk for HIV.

Stigmatizing institutional values and health care norms shape HIV services

HIV and sexual health services are important factors that may shape GBMSM's risk of HIV. In 11 studies reviewed, stigma was related to reduced intention and utilization of sexual health services, such as HIV testing, PrEP, and ARVs (Amirkhanian et al., 2011; Ancker & Rechel,

2015; Evangeli et al., 2016; Longfield et al., 2007; Navaza et al., 2016; Nöstlinger et al., 2014; Pachankis, Hatzenbuehler, Berg, et al., 2017b; Peng et al., 2018; Sidebottom et al., 2018; Stojanovski et al., 2019; Stojisavljevic et al., 2017). Research from Bosnia & Herzegovina and North Macedonia portrayed the stigmatizing experiences of GBMSM at health centers that create challenges with accessing government services (Stojanovski et al., 2015; Stojanovski et al., 2019; Stojisavljevic et al., 2017). Similarly, stigma in Spain and the Netherlands was described as a barrier to health services (Navaza et al., 2016; van Opstal et al., 2018). In Central Asia, health professionals enacted stigma against GBMSM and GBMSM hide their orientation, fearing discrimination, thus further hampering prevention efforts (Ancker & Rechel, 2015). A systematic review focused solely on Europe showed that fear and stigma influence intentions to test for HIV (Deblonde et al., 2010). Lastly, the findings indicated that concerns about confidentiality and discrimination shaped the use of HIV services, particularly HIV testing, across the entire European continent (Hoyos et al., 2013; Longfield et al., 2007; Navaza et al., 2016; Nöstlinger et al., 2014; Stojanovski et al., 2015; Stojanovski, et al., 2019; Stojisavljevic et al., 2017; van Opstal et al., 2018).

Institutional-level stigma played a part in creating an ecosystem of HIV risk that intersected with other identified intermediary and direct risk factors. The institutional level norms that stigmatized GBMSM had pathways to HIV risk, such as perpetuating poor mental health and altering use of services. The institutional factors interacted with other risk factors to socially pattern HIV.

Stigmatizing policies shape the HIV risk environment

Relatedly, stigmatizing policies may influence sexual behaviors and sexual health service use. In a 38 European country study, protective SGM policies were associated with higher

perceived control over sexual risk-taking (Ross et al., 2013). A global survey among trans men that included Europe indicated that criminalization of trans identities was associated with reduced access to condoms (Scheim et al., 2016). Research from Kazakhstan, Kyrgyzstan, Turkmenistan, and Uzbekistan showed that social stereotyping and low awareness of human rights protections resulted in more stigma (Ancker & Rechel, 2015). In the same study, GBMSM reported concealing their sexual orientation because of fear of legal prosecution (Ancker & Rechel, 2015). Kelly et al. found that limited political will or opposition to HIV prevention was cited as a barrier to service provision among NGOs (Kelly et al., 2006). A study that explored the political contexts in Eastern Europe and Central Asia (EECA) found that stigmatizing laws, such as the criminalization of homosexuality, sex work, and drug use, shape HIV service efforts (Gotsadze et al., 2019). A cross-European study showed that anti-gay structural stigma was associated with higher odds of inadequate HIV prevention coverage, use of services, and limited disclosure of sexual orientation (Pachankis et al., 2017a). Lastly, homophobia is also associated with a higher number of AIDS-related deaths (Lamontagne et al., 2018). As elaborated in the research, the cultural and social norms of homophobia, sexism, and misogyny shaped policy and legislation that socially pattern HIV risk among GBMSM.

The systematic review also found that stigmatizing policies can shape mental health, which, as described earlier, can influence HIV risk. In a European study of 38 countries, GBMSM living in countries without legal rights and protections had the highest homonegativity scores (Ross et al., 2013). A study in Russia found that GBMSM, who completed their surveys after St. Petersburg passed local anti-gay ordinances, as compared to before the ordinance passed, had a 1.7 higher odds of depression [AOR=1.65 95% CI (1.23-2.22)] (Hylton et al., 2017). GBMSM in the study who experienced interpersonal stigma and who took the survey after the passage of the

ordinance experienced a two-fold greater chance of depression than those with no experienced stigma (Hylton et al., 2017). Linking these findings to the previous individual-level findings, which showed that mental health alters sexual behaviors, implicates the role of stigma in patterning HIV risk among GBMSM.

Policies shape access to HIV and sexual health services

Policies, writ large, may directly influence GBMSM's ability to access HIV and sexual healthcare services. In a systematic review of barriers to HIV testing in Europe, Deblonde et al. found numerous structural and policy-level barriers existed, such as accessibility of health services (Deblonde et al., 2010). Healthcare financing of HIV treatment and prevention services can also influence GBMSM's risk of HIV. For example, PrEP is a critical tool in preventing HIV on the European continent (McCormack et al., 2016; Molina et al., 2015). However, PrEP provisioning, uptake and adherence are also influenced by governmental policies (Sidebottom et al., 2018). As uncovered from the systematic review, policies play an instrumental upstream role in shaping HIV risk among GBMSM.

Macroeconomics can shape the HIV risk environment

Macroeconomic factors, such as the economy and the country's gross domestic product (GDP), can also influence the HIV risk environment. The review of articles indicated that a country's income categorization affects the homophobic climate (Baral et al., 2007; Lamontagne et al., 2018). As described earlier, homophobic cultures can shape numerous factors within the HIV risk environment. In Peng et al.'s study the acceptability of PrEP was reduced if GBMSM had to pay for it (Peng et al., 2018). A systematic review that included 12 European nations found that GBMSM in low-income countries had an 7.8 odds of HIV infection (95% CI 7.2–8.4), as compared to 23.4 in middle-income countries (95% CI 22.8–24.0) (Baral et al., 2007). Kelly et al.

found that NGOs are heavily dependent on foreign donors to provide keys services for HIV and the limited funding hampers HIV services (Kelly et al., 2006). These results portrayed how macroeconomics also play a role in socially patterning HIV risk toward GBMSM.

Dynamic and emergent nature of HIV risk and infection

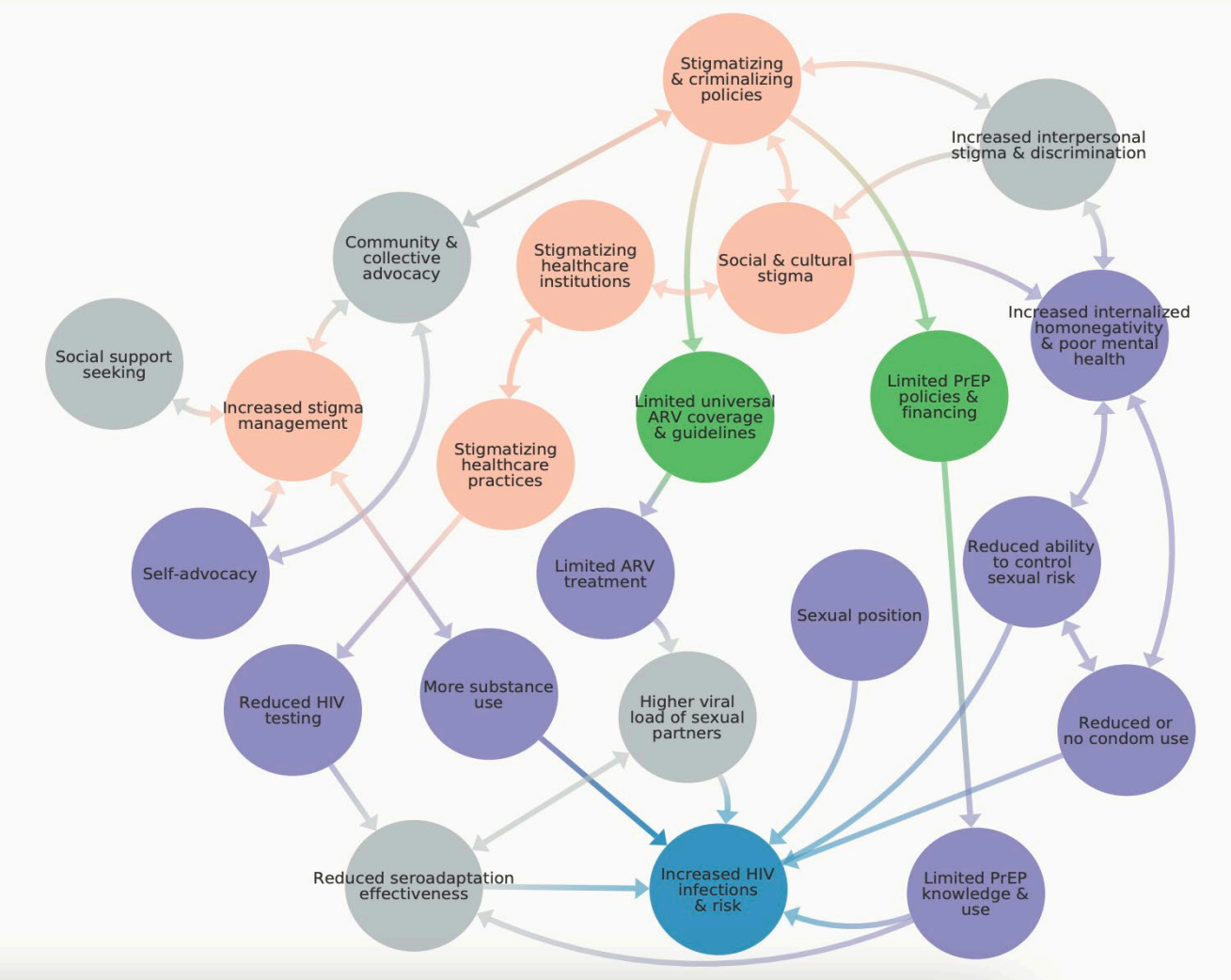
In totality, the amalgamation of studies' findings and the exploration of the relationships suggested that stigma has direct and indirect effects on a multiplicity of risk factors for HIV. This systematic review indicated that stigma serves to socially pattern risk factors in numerous ways, such that the ecosystem of HIV risk disproportionately burdens European GBMSM (Figure 3). This conceptual model positioned that stigma structured GBMSM's access and use of services, including HIV testing; reduced GBMSM's intentions, capabilities, and abilities to prevent HIV; and shaped GBMSM's mental health and sexual behaviors. The totality of these relationships influenced the emergence of HIV risk and infection in ways that disproportionately burden GBMSM.

Risk of bias of the studies and review

With all systematic reviews there are risk of biases given that the strength of the review relies on the strength of the research studies themselves. In general, the biggest thematic biases that arose were three-fold. First, majority of the literature examining HIV risk factors in Europe still rely on cross-sectional studies. With cross-sectional studies reverse causation may be an issue, which is why bidirectional arrows were used for relationships that were not supported with longitudinal data or theoretical relevance in the conceptual model (Figure 3). Second, given that GBMSM are considered "hard to reach" because of the structures that marginalize them, selection bias of participants is a concern given the sampling methods used (e.g., purposive or respondent driven sampling). The studies that use non-random sampling cannot be generalized to other

populations outside the study, however these sampling methods are critical and used widely given the limited capacity of random sampling to reach GBMSM. Lastly, recall bias is a challenge given that much of the literature still relied on self-reported behaviors and information. However, self-report remains one of the only strategies available to collect information on sexual behaviors, attitudes, and knowledge. Despite these limitations, the use of systematic reviews as primary data sources, incorporation of longitudinal studies, and the large number of studies reviewed, across diverse contexts, strengthen the systematic review and visualization conducted in this chapter of the dissertation.

Figure 3. Complex systems visualization of HIV risk among European gay, bisexual, and other men who have sex with men



Legend

Blue=Outcome
Peach=structural/policy-level factors
Green=organization/institutional-level factors
Gray=community-level and interpersonal-level factors
Purple= individual-level factors

Discussion

The analyses presented in this chapter suggested that HIV infections among European GBMSM arise from a dynamic and complex interplay of factors influenced by the various manifestations of stigma as this chapter suggests. The visualization that was developed for aim one portrayed that stigma played an intricate role in the patterning of HIV risk and infection among European GBMSM by shaping the upstream and downstream social processes and behaviors. The use of complex systems theory allowed for the visualization of the web of factors that burden GBMSM with elevated HIV risk in Europe. The resulting conceptual model indicated that a focus on the structural determinants and more upstream interventions, with a particular focus on stigma's role, are needed to fully address the interactional and collective risk that GBMSM experience.

The application of complex systems models is slowly increasing within public health to understand how numerous intersecting processes shape one's health risks. A recent agent-based model (ABM) of a complex system explored U.S. racial inequities in PrEP. Goedel et al. showed that while increasing PrEP uptake will reduce overall HIV infections, it will do nothing to address HIV disparities (Goedel et al., 2018). In fact, in the model, when Black and White agents are shown to use PrEP at equal rates, the HIV disparity ratio between the two groups increased because the underlying disparity was never addressed (Goedel et al., 2018). Goedel's findings indicate the need for efforts to simultaneously address the multitude of risk factors such as accessibility, acceptability, and quality of healthcare service, which align with the findings of HIV risk in this dissertation chapter. Scholars such as Marshall et al. have explored how combination HIV intervention strategies may be necessary given the complexity in which HIV is socially patterned (Marshall et al., 2012). As this study visualized, numerous intersecting and overlapping factors

can shape HIV risk in Europe. Research and interventions must adequately address the role of stigma in creating an entangled system of HIV risk.

Dissertation aim one identified the intersecting processes that work together to structurally influence the emergence of HIV risk and infection among European GBMSM. The conceptual model of the intersecting risk factors aligns with Rhodes et al.'s concept of the "[HIV] risk environment," which shifts the focus from individual behavioral risks toward the social and structural processes (Rhodes & Simic, 2005). Global responses, such as the Joint United Nations Programme on HIV/AIDS (UNAIDS) 90-90-90 goals (90% of PLHIV know their status, 90% of PLHIV are on sustained treatment, and 90% of PLHIV have a suppressed viral load), must pay particular attention to how stigma structures HIV risk behaviors and prevention efforts. Scholarship implores us to think of interventions not merely as a "package" of activities, but rather, alternatively, to focus on the dynamic processes of the environment and context where interventions are introduced (Hawe et al., 2009). The focus on the dynamic processes that shape HIV risk is particularly important, which, as this chapter showed, arises from multi-faceted processes. The visualization indicated that stigma and its influence on risk factors such as mental health, sexual behaviors, and HIV services, work in concert to weaken the capacity of European GBMSM to reduce their risk for HIV infection. Development of ABM's that simulate the dynamic nature and processes visualized can better identify the cumulative effect of the risk factors. Future research should explore how interventions may disrupt the role of stigma in perpetuating HIV risk and diagnosis among European GBMSM to enhance prevention efforts.

Limitations and future research

Limitations in the synthesis of the research include aspects of the approach used and the generalizability. While I used a systematic review procedure, the processes outlined in Figure 3

may not be exhaustive. The dynamic processes will change over time as scientific research and interventions take place. The conceptual model can be leveraged in future research to better hypothesize and study the mechanisms of action in different environments, geographies, and interventions. Additionally, I was the sole reviewer of the studies. However, I explicitly included systematic reviews as data sources given the evidence-based manner in which systematic reviews are conducted. Nine out of the ten systematic reviews that were included had two or more reviewers, which reviewed over 400 studies. The tables and results were also shared with the committee to improve the interpretation and development of the themes. Lastly, many of the pathways developed were identified as associations, given many studies' cross-sectional nature. Cross-sectional studies limit the interpretation of causal effects. However, a growing body of global scholarship provides causal evidence to some of the pathways elucidated in the visualization in this chapter (Mimiaga et al., 2015, 2019; Rodger, Cambiano, Bruun, Vernazza, Collins, Van Lunzen, et al., 2016; Velloza et al., 2020). Future research would benefit from automating systematic review processes through the use of natural language processing (NLP) to enhance synthesis of the research literature. NLP is an interdisciplinary field including computer science, artificial intelligence, and linguistics. NLP is a collection of algorithms that can be used to identify, extract, parse, and analyze textual data, such as written text in journal articles. The text itself becomes the unit of analysis. NLP can be used to examine the absence or presence of certain words, identify relationships between words, and explore the content and patterns in the phrases used in the research literature (Dreisbach et al., 2019). The use of NLP could help to validate the systematic review of this aim, especially if additional longitudinal studies are included.

Conclusion

HIV risk among European GBMSM is socially patterned due to numerous dynamic and intersecting risk factors in which structural stigma plays an important role. Structural stigma shapes overlapping factors that work in tandem to influence the emergence of HIV risk and diagnosis among European GBMSM by weakening GBMSM's capacities to prevent HIV. The dynamic nature of HIV risk needs to be further examined to enhance HIV prevention efforts.

Chapter 3. An Agent-Based Model to Explore Stigmatizing Policies' Role in Socially Patterning HIV Risk and Infection Among European Gay, Bisexual, and Other Men Who Have Sex With Men

Abstract

A diverse body of literature portrays numerous factors that influence HIV risk and diagnoses. Mental health, fear of discrimination, alcohol use, and sexual risk behaviors are all related to HIV risk and diagnosis. However, research has not been done to fully understand how heterogenous and intersecting factors together perpetuate the very risk factors that are associated with HIV diagnosis. The goal of the second dissertation aim was to study how HIV risk emerges from diverse interacting factors stemming from stigmatizing policies. **To study HIV as a collective outcome of diverse processes, I developed an agent-based model (ABM).** The ABM examined how stigmatizing policies affect interpersonal discrimination, shape GBMSM's mental health, alter sexual behaviors and ultimately, increase HIV risk and diagnosis. I ran 10,000 Monte Carlo simulations for each level of a "stigmatizing policy" with 100 different populations of 1,500 agents simulated 100 times at each policy level. I conducted adjusted forward stepwise logistic regression models by iteratively including one additional parameter into the model during each step to explore how relationships changed. The ABM indicated that HIV risk arises from complicated relationships and stochastic processes. Small variations in the relationships between the parameters created implications for HIV risk behaviors and diagnoses among the GBMSM

agents. When the “policies” in the model were more stigmatizing, which elevated gay agents’ experiences of discrimination, that in turn heightened homonegativity, that then increased compulsive sexual behavior in the model and, ultimately, HIV “diagnosis.” The ABM suggests that stigmatizing policies play an upstream role in shaping an environment that elevates the burden of HIV risk among GBMSM agents. The specific aim of this chapter was used to generate hypotheses that I subsequently explored in aim three, which assessed to what extent countries' SGM policies interact with downstream individual-level factors to influence GBMSM’s HIV serostatus using real-world European survey data.

Introduction

To continue exploring the complexity of risk factors outlined in Chapter 2*,* this chapter of the dissertation aims to model a pathway identified in the complex systems visualization.

Numerous factors are related to HIV risk among European gay, bisexual, and other men who have sex with men (GBMSM). In Western Europe, HIV is concentrated among GBMSM, similar to the U.S. (World Health Organization, 2018). Eastern Europe experiences the brunt of the increasing incidence on the continent, and persons who inject drugs (PWID) and GBMSM are among those most at risk (DeHovitz et al., 2014; Gokengin et al., 2018).

Research implicates stigma in perpetuating HIV risk among GBMSM (Crepaz et al., 2014; European Centre for Disease Prevention & Control, 2017; Jackson-Best & Edwards, 2018; Longfield et al., 2007; Mimiaga et al., 2015; Storholm et al., 2016). Studies indicate that HIV risk is shaped by numerous processes, such as decisions not to test for HIV, fear, experiences of discrimination, poor mental health, and sexual behaviors (Baral et al., 2007; Deblonde et al., 2010; Mimiaga et al., 2015, 2019; Stojanovski et al., 2019; Stojisavljevic et al., 2017; Velloza et al., 2020; Wade et al., 2017). Given the diversity of factors that influence HIV risk, improved models that explore the cumulative effects of the multitude of interactions across risk factors would advance HIV research. The use of complex systems, an interdisciplinary field that studies how numerous components within the system interact with each other to produce health disparities, may help identify how stigma creates a risk environment that burdens GBMSM with heightened HIV risk. As Chapter two of this dissertation portrayed there are countless interactions and feedback loops that may shape the environment in such a way that perpetuates HIV risk and diagnosis among GBMSM in Europe.

Agent-based modeling (ABM) is a modeling technique in systems science that allows for studying social phenomena, cultural transmission, disease propagation, and human behavior. ABMs study the collective outcomes of diverse, dynamic, and complex processes comprised of numerous interacting factors (Langellier, 2016; Langellier et al., 2019). Thomas Schelling created the first simple ABM in 1969 that modeled the occurrence of neighborhood segregation. In the Schelling model, "agents" had preferences regarding the "color" of their neighbors. The study showed that even small "preferences" for people of the same "color" had large emergent effects that produced segregation, *even without incorporating the racist structural policy processes at play* (Schelling, 1978). Incorporating the structural dimensions within ABMs may provide additional information about how stigmatizing structures shape health (in)equity, and for this dissertation, HIV risk and diagnosis.

In ABM, agents are the "person," with each agent having internal states (properties) and behavioral rules (actions and rules) (Epstein & Axtell, 1996). ABMs have an environment and context in which the agents "interact" within, including time. Each part of the system, whether the properties, actions, rules or environment may be fixed or changed, contingent upon agents' interactions in the modeled environment and their relationships to one another. The Properties, Actions, Rules, Time, and Environment (PARTE) framework defines an ABM's elements (Hammoud, 2015). The properties, actions, and rules are elements that define the agent ("person") and their relationship to one another. Time and environment determine the context or "structure."

A growing body of sexual health research has begun to use ABMs to understand the impact of diverse factors related to STI and HIV infection. Rutherford et al.'s ABM showed that STI infections drop steeply with a 60% condom use rate over ten years (Rutherford et al., 2012). However, at an 80% condom use rate, the decline in STI infections becomes attenuated because

other factors such as the number of sexual partners and testing behaviors also impact the rate of HIV diagnoses in the ABM (Rutherford et al., 2012). Rutherford's ABM enabled the prediction of STI reductions while also accounting for complex individual-level behaviors and structural limitations. Another ABM study by Gantenberg et al. showed that incremental changes in pre-exposure prophylaxis (PrEP), an HIV prevention medication, helped reduce HIV infections (Gantenberg et al., 2018). They estimated that if agents had over five sexual partners and a zero percent PrEP coverage rate, the HIV infection rate would be an estimated 826 infections over ten years. However, as the PrEP coverage rate improves, the ABM provides estimates on the potential infections averted. At a 5% coverage rate, there would be 89 fewer cases of HIV (10% reduction). While at the 30% coverage rate, there would be an estimated 422 infections averted (over 50% reduction) (Gantenberg et al., 2018). Such modeling techniques can improve the HIV research literature to better support intervention development by understanding how dynamic processes produce collective outcomes.

While the field is growing, there has been no application of ABMs to explore how structural stigma (e.g., stigmatizing policies), and the unfolding processes it produces, lead to HIV risk and diagnosis. A global body of literature has emerged illustrating how stigma, such as stigmatizing policies (e.g., criminalizing same-sexual activity) and experiences of interpersonal discrimination, create adverse downstream effects on mental health, sexual behaviors, access to health services, and HIV treatment and prevention (Joint United Nations Programme on HIV/AIDS, 2014; Lane et al., 2008; Lee et al., 2016; Meyer, 2003; Mimiaga et al., 2015; Storholm et al., 2016). Experiences of stigmatizing stressors (e.g., discrimination) are related to mental and behavioral health issues, such as drug use, which elevate one's risk for HIV (European Centre for Disease

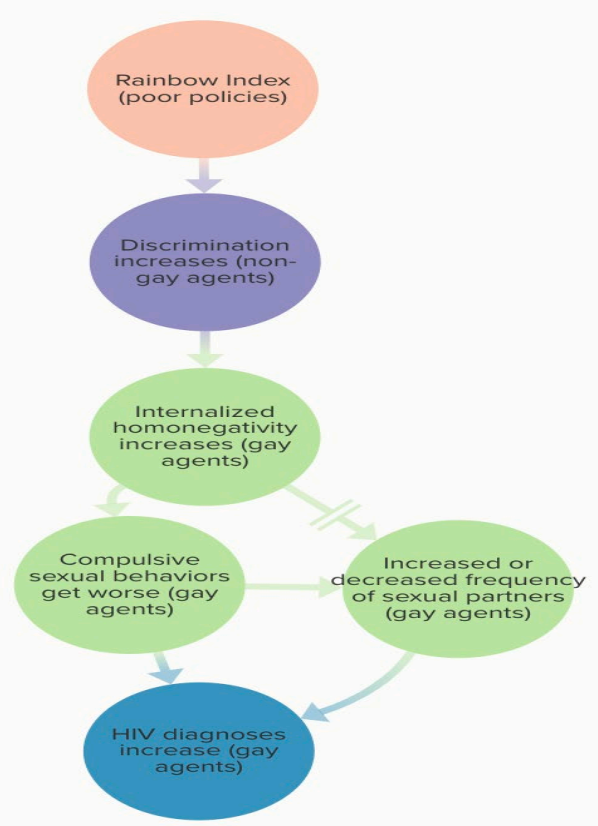
Prevention & Control, 2013). Stigma amplifies other risk factors, requiring improved conceptualizations of HIV risk to understand the dynamic role that stigma performs.

While ABMs are growing, they have been predominately used to model population health outcomes in the U.S. The use of complex systems and ABM is a very promising tool to understand the influences of stigma on HIV risk and diagnosis in global contexts. This dissertation chapter explores how "stigmatizing policies" influence HIV prevalence and the direct and indirect risk factors among European GBMSM in a simulated agent-based model (ABM). Aim two is a proof of concept aim whose goal is to generate hypotheses about the dynamic and interactional nature of HIV risk to be examined in aim three (Chapter four of this dissertation).

Methods

The ABM used a pathway that I identified in the previous thematic analysis presented in Chapter 2. This pathway was chosen given the research literature that explores these relationships (but not in one single study). I used the PARTE framework to develop the algorithms' rules, outlined in the following areas: agent characteristics, environmental characteristics, and interactional behaviors (Hammoud, 2015). In Figure 4, I portray the modeled system.

Figure 4. The complex system modeled in the ABM



Legend
Broken line between homonegativity and frequency of sexual partners means a negative association
Blue=Outcome
Peach=structural/policy-level factors
Green= individual-level factors

Environmental characteristics

The environmental characteristics of the ABM constitute the structural level. For this ABM, the environment comprises of country-level policies regarding the protection and fulfillment of SGM rights. I used the Rainbow Index for the structural parameter. The International Lesbian, Gay, Bisexual, Transgender, and Intersex Association (ILGA) of Europe created the Rainbow Index to measure structural stigma (ILGA Europe, 2010). Countries received positive points if they had protective legislation, for example, recognizing same-gender partnerships, presence of parental rights for same-gender couples, and inclusion homophobia or transphobia in

hate speech/crime legislation. Countries received negative points if they did not have protective laws or had laws that violated human rights. The index weighs SGM rights differently. For example, anti-discrimination protections accounts for 25% of the score. For 2010, the Rainbow Index scores ranged from between 10 (maximum positive score) and -4 (maximum negative score). I changed the range from 14 to one to keep the Rainbow Index a positive value to reduce complexity in the model. During the ABM, each turn of the "clock" constituted a future theoretical state of the system. I simulated each policy-level from 1-14, allowing the interactions to unfold, as outlined in Table 3. These structural level parameters encompass the environment and time portion of the PARTE framework.

Agent characteristics

I included two agents: GBMSM (40% of the model's agents) and heterosexual agents (60% of agents in the model). I had a total population of 1,500 agents. I chose the values to ensure that there would be enough gay agents for interactions to occur. However, different and varied values could be modelled, which I will discuss in the limitations. For my model's initial values, I first ran the model at policy-level 14 to allow the parameter values to reach a steady state, which means that the parameters in the model achieved constancy. I derived the initial starting values for the steady-state (policy 14) simulations from the literature (Table 1). I subsequently used the averages and standard deviations from the steady state simulations to initialize the values (constants) for the parameters in the full ABM.

Heterosexual agents had a parameter that defines whether they had discriminatory behaviors, ranging from zero (no discrimination) to one hundred (full discrimination) aligned with the measurement from the European Values Study (Directors, 2017). This property of the heterosexual agents was used during interactions between heterosexual and non-heterosexual

agents to simulate the experience of interpersonal discrimination. The higher the values, the more interpersonal discrimination experienced by GBMSM agents during interactions with heterosexual agents. The starting value for discrimination was a mean of 0.039 and a standard deviation of 0.71.

GBMSM agents had the following parameters and starting values that I incorporated from the steady state simulations (Figure 4):

- Internalized homonegativity (mean=0.00187, standard deviation=0.0694), which was on a scale from one to six, (Ross et al., 2013);
- Compulsive sexual behavior (mean=0.00523, standard deviation=0.0997) with a possible range of zero to 45 (Smolenski et al., 2011);
- Experiences of discrimination, which is embedded within the homonegativity equation in Table 3;
- Condom use desires (30% desired condom usage at onset);
- Desired frequency of sexual partners, which were grouped as follows: 20% had zero partners, 45% had 1-4 partners, 10% had 5-10 partners, 20% had 11-50 partners, and 5% had 51 or more partners (European Centre for Disease Prevention & Control, 2013);
- HIV serostatus grouped as such: 89% started as HIV negative serostatus, 11% were HIV positive serostatus, of which 40% were positive and unknown, 50% were undetectable, and 10% were positive, and known, but not yet achieved viral suppression (European Centre for Disease Prevention & Control, 2013); and
- Top sexual position (50% of gay agents) and bottom sexual position (40% of gay agents), and 10% were based on chance (flip of a "coin").

I defined each agent's sexual position (i.e., penetrative or insertive) during a sexual encounter through a 50%-50% coin flip at each sexual encounter in the model based on the

changing values emerging from the interactional effects of the parameters in the ABM. These individual parameters encompass the properties portion of the PARTE framework. I outline each parameter's initial starting values for the full ABM in Table 3. I also describe in Table 3 the mathematical equations that govern the interactions between the agent's parameters and the environment. The equations define the Rules section of the PARTE framework. The equations included are for the respective parameter described within each specific row.

Table 3. Initial parameter values and the mathematical equations governing the relationships between the parameters of the agent-based model

Parameter	Equation	Article equations developed from
Policy (time + 1)	• The initial value starts at 14 (good policies) and then drops to one (bad policies) • $maxpolicy \times ((\frac{time}{60+time}) + 1)$	ILGA-Europe, Rainbow Index 2010

Discrimination (time+1)	• Initial values for policy 14 only simulations
	  ○ Mean=38.9, Stdev=4.88
	  ○ Range: 0 (no discrimination) – 100 (high discrimination)
	• $(100 + \left(-\frac{100}{maxpolicy}\right) x\ policy + \frac{discrimination(time-1)}{2})$
		Berg et al. 2013

Homonegativity (time + 1)	• Initial values for policy 14 only simulations
	  ○ Mean=1.82, Stdev=1.23
	  ○ Range: 0 (no homonegativity) – 6 (high homonegativity)
	• $Homonegativity(time-1) + 0.11\ x\ discrimination + 0.584 \times policy$
		Berg et al. 2013

Condoms (time + 1)	• $\frac{1-(homonegativity(time-1)}{6}$ • The odds of using a condom are reduced by 1.2 with every unit change in homonegativity (e.g., if homonegativity is six, then using a condom is reduced by 7.2). • This pushes the condom use variable to either zero (no condoms) or one (yes condoms).	Ross et al. 2013

Desired frequency of sexual partners (time + 1)	• Initial values all simulations ○ 20%: zero partners, 45%: 1-4 partners, 10%: 5-10 partners, 20%: 11-50 partners, 5%: 50+ partners • $\frac{\#\ of\ partners\ (time-1)-0.15\times\frac{homonegativity(time-1)}{6}+0.8\times\frac{comp}{}}{2}$	Smolenski et al. 2011

Compulsive sexual behavior (time + 1)	• Initial values for policy 14 only simulations
	  ○ Mean=2.62, Stdev=0.8
	  ○ Range: 0 (no compulsive sexual behavior) - 65 (high compulsive sexual behavior)
	• $\frac{Compulsexbehav(time-1)+0.43\times\frac{homonegativity(time-1)}{6}}{2}$
		Smolenski et al. 2011

HIV infection (time + 1)	• If negative top:
	  ○ Sex with an unknown detectable bottom with no condom, then the probability of infection is 0.0011.
	• If negative bottom:
	  ○ Sex with unknown detectable top with no condom, then the probability of infection is 0.0138.
	• If a condom is used, then the probability of infection is reduced by 70%.
	• The time it takes to change from detectable to undetectable ranges from 4-6 months.
	• No transmissions will occur if a sexual partner is undetectable and the other is negative.
		Condom effectiveness, Weller et al. 2002
		
		Probabilities of infection, Centers for Disease Control and Prevention

Sex (time + 1)	• Sex occurs when a gay top & bottom agent meet, share the same desires for condom use (will use condoms or not use condoms), and the threshold for sexual partners' frequency is not reached.	

Interactional behaviors

The ABM has interactions that occur, which are bound by rules and actions developed into the PARTE framework, which governs the relationships in the model. The interactions and the rules are directed by loops of code (as seen in the Appendices) and the mathematical equations outlined in Table 3. The ABM was developed in such a way that as time moves forward, agents

move around and can "meet" another agent. When this occurs, agents assess their "location" in the environment and then each other's sexual orientation. If one agent is GBMSM and another heterosexual, depending on the heterosexual agent's discrimination value, they will discriminate against the GBMSM agent. This gets incorporated into the internalized homonegativity equation of the gay agents. As outlined, in the equations as the policy gets worse, the probability and impact of discrimination are amplified given the dynamic nature of the model.

In the model, if interacting agents are GBMSM, then there is a probability they will have sex. First, gay agents will see how many sexual partners they had sex with and stop if they met their maximum threshold. Then, GBMSM agents will assess each other's sexual positions (only a top and bottom agent pair will have anal sex). GBMSM agents would then update their internalized homonegativity scores based on their experiences of discrimination. After this, the internalized homonegativity can shape the sexual behaviors of the GBMSM agents. For example, increased internalized homonegativity would elevate compulsive sexual behavior, decrease the desire for more sexual partners, and potentially reduce condom use within the ABM as outlined in the equations in Table 3. After the updates to discrimination, homonegativity, and sexual behaviors, GBMSM agents assess the potential partner's HIV status. With all the information, agents will then decide whether they want to have sex (i.e., sexual position aligns, haven't met the threshold for partners, etc.). The ABM allows for the chance that agents do not perform the "anticipated" behavior to allow for additional stochasticity in the model. The model does not incorporate more heuristic or emotion focused decision-making as that was not a focus of this dissertation, although these could further pattern the risk factors.

If sexual interaction occurred, GBMSM agents would then update their HIV statuses, if necessary. If one of the agents were either HIV positive unknown, or HIV known detectable, HIV

transmission is probable. HIV transmission will also depend on whether condoms are used and the sexual position. If a gay agent does not have a strong preference for condoms, then a coin is tossed with a 50-50% probability of condom use (although this will change as internalized homonegativity changes). Also, HIV statuses can change. Every 3 and 6 months, gay agents with HIV will update their status from unknown to known status, and then another 3-6 months to potentially move to undetectable status.

For the interactions, I used the following probabilities for HIV infection as a baseline: 138 infections per 10,000 exposures (0.00138) for receptive condomless anal intercourse and 11 infections per 10,000 exposures (0.00011) for insertive condomless anal intercourse. These probabilities change depending on the interactions described above. For example, if condoms are used, HIV risk can be reduced by 70-100% (random probability), which were included in the ABM (Pinkerton & Abramson, 1997).

Algorithm development and modeling outcomes

The algorithm was developed over the course of a two year period in Python (Van Rossum & Drake Jr, 1995). I developed the original algorithm for a complex systems course, which was used for this dissertation chapter. For this algorithm, I supervised a research assistant (RA) to enhance the original code for the new interactions and complexity. ABM coding is a bottom-up approach, starting with the simplest algorithm and getting more complex. As a first step, the research assistant (RA) and I each developed a pseudocode. Pseudocode is a standard coding practice that outlines the steps in an algorithm in plain language form, rather than in coding language. After this step, the RA and I compared our pseudocodes for validation. The pseudocode and original code were then used to build the algorithm. The algorithm coding was an iterative process over an eight month period using a pair programming method to enhance the quality of

the algorithm (Williams et al., 2002). Pair programming is a computer science programming method where both coders work on the algorithm together, at the same computer, in real-time to code, troubleshoot, and test. In addition to pair coding, we spent time separately coding and adjusting the code to ensure the loops were functioning properly and validate the outcomes of the modelling aligned with the equations in Table 3. The RA and I started with a simple model, incorporating the downstream factors, such as HIV status (negative or positive), sex, top or bottom position (versatile was not included), and frequency of partners. At each subsequent step we introduced more complexity into the code. In the second step, we introduced the discrimination and homonegativity parameters. In step three, the policy variable was coded. In the fourth iteration, we incorporated compulsive sexual behavior and condom use into the model. After each iteration of the code validation checks were completed by assessing whether the emergent effects being produced aligned with the mathematical equations to ensure the loops of code were functioning as intended. A similar pair-coding method was used with Dr. Eisenberg to validate and update the mathematical equations and refine the algorithm during working sessions.

The collective outcomes of interest are HIV infection. To assess the consequences of the dynamic relationships, I conducted parameter sweeps for all levels of the Rainbow Index and associated changing parameters using Monte Carlo simulations. Monte Carlo simulation is a technique that examines the degree of variation in the model's output (i.e., HIV sexual risk behaviors and HIV diagnosis) that arise from the many interactions of stochastic (random and probabilistic) processes and behaviors in the model (Rubino & Tuffin, 2009). For this ABM, the Monte Carlo simulations allowed simulation of "stigmatizing policies." The simulations explore how stigmatizing policies relate to GBMSM agents' experiences of discrimination, internalized homonegativity, sexual behaviors, and ultimately HIV diagnosis. Monte Carlo simulations allow

for different populations of the gay and non-gay agents to simulate through the equations by placing them into different policy contexts to capture the emergent nature of HIV diagnosis (i.e., examining how the system (re)produces HIV infection). I ran 10,000 simulations for each policy level with 100 different populations of 1,500 agents each simulated 100 times at each policy level. This was done to capture the full range of stochastic processes that might fuel HIV risk and diagnosis.

Statistical analyses of ABM data

The simulations produced a dataset for exploring the collective outcomes of the stochasticity in the model parameters to generate hypotheses. I explored to what extent experiencing "stigmatizing policies" shapes HIV risk and diagnosis. I utilized univariate analyses to understand the simulated data, including means, medians, ranges, and standard deviations for continuous parameters. For categorical parameters, such as HIV serostatus, I used frequencies and percentages. Table 4 presents the parameters explored in the statistical analyses.

Table 4. Parameters examined in the statistical analyses

Parameter	**Article equations developed from**
Policy, ranges from zero (bad policies) to 14 (good policies)	ILGA-Europe, Rainbow Index 2010
Discrimination, ranges from 0 (no discrimination) to 100 (full discrimination)	Berg et al. 2013
Homonegativity, ranges from 0 (no homonegativity) to 6 (full homonegativity)	Berg et al. 2013
Condoms, defined as percentage of time used	Ross et al. 2013
Frequency of sexual partners, full range from zero to infinity	Smolenski et al. 2011
Compulsive sexual behavior, ranges from 0 (no compulsive sexual behavior) to 65 (full compulsive sexual behavior)	Smolenski et al. 2011
HIV infection, yes or no	Probabilities of infection, Centers for Disease Control and Prevention

Sex, defined as number of sexual encounters	

I used unadjusted linear regression models to explore the relationships between policies and the non-count parameters (i.e., internalized homonegativity, compulsive sexual behavior, discrimination, and a preferred number of sexual partners). I used unadjusted Poisson regression for count variables (i.e., number of times condom use and number of sexual encounters). I present the results with beta estimates and 95% confidence intervals. I also conducted unadjusted logistic regression models to examine the relationship between HIV serostatus (dichotomized as yes or no) and the parameters.

For the adjusted models, I conducted forward stepwise logistic regression models by adding one additional parameter into the model to explore how relationships changed. Model one included proximal risk factors (i.e., preferred sexual partners, condom use, and compulsive sexual behavior). In the second model, I included internalized homonegativity. For model three, I added the discrimination score. For the fourth model, I incorporated the policy-level parameter. In the final model five, I included the number of sexual encounters that took place. For all the models, I present the odds ratios and 95% confidence intervals. While I present statistical results to examine the model outputs, the statistical calculations and values are not designed to estimate the size of the effect. Rather, the statistical analyses are used to examine the dynamic nature of the processes to explore how they change in relation to each other to generate hypotheses for testing in Chapter four. In addition, the interpretation of the results, rather than the statistical values themselves are more important in the analyses of ABMs.

Results

Univariate analyses of indirect & direct risk factors & HIV status

In total, the Monte Carlo simulations produced 53,621,400 different interactions. The mean number of gay-gay agent interactions per gay agent was 26.13, ranging from zero to 65. The mean number of sex acts per gay agent was 0.31, ranging from zero to 19. The mean number of HIV exposures per gay agent (sex between an HIV negative agent & HIV positive, detectable agent) was 0.01 and went from zero to five. The mean number of sexual partners among gay agents was 11.73 (median: 3.0), ranging from zero to 100 (Table 5). Overall, in the model, there was a low number of sexual interactions, which is discussed later.

Table 5. Mean, medians, and ranges of ABM interactions, sexual encounters, condom use, and exposures among gay agents

	Mean	Median	Range
# of gay interactions	26.13	26.00	(0, 61)
# of sexual interactions	0.31	0.00	(0,19)
Average # of sexual partners	11.73	3.00	(0, 100)
# of times condoms used	0.30	0.00	(0, 19)
# of exposures	0.01	0.00	(0, 5)

In total, 89% (n=39,568,468) of gay agents were HIV negative, 6% (n=2,488,889) were undetectable, 4% (n=1,927,230) living with HIV, yet unknown, and 1% (n=547,113) living with HIV, status aware, but not yet achieved viral suppression (Table 6).

Table 6. Frequencies and percentages of HIV statuses

HIV status	N	%
Negative	39,568,468	89%
Undetectable	2,488,889	6%
HIV positive known	547,113	1%
HIV positive unknown	1,927,230	4%

The mean discrimination score of non-gay agents was 53.3, ranging from zero to 86. The mean homonegativity score of gay agents was 0.01 and went from zero to 2.36. The mean compulsive sexual behavior score of gay agents was 0.0013 and ranged from zero to 0.47 (Table

7). The average homonegativity and compulsive sexual behavior scores in the model were small, as compared to the operationalization of the scales.

Table 7. ABM parameters means, medians, and ranges

Parameters	Mean	Median	Observed range	Theoretical range
Discrimination score (non-gay agents)	53.3	57.1	(0, 85.7)	0-no discrimination to 100-high discrimination
Homonegativity score (gay agents)	0.01	0.01	(0, 2.36)	0-no homonegativity to 6-high homonegativity
Compulsive sexual behavior score (gay agents)	0.0013	0.0004	(0, 0.47)	0-no compulsive sexual behavior to 65-high compulsive sexual behavior

Unadjusted associations of the Rainbow Index with parameters

In unadjusted analyses, the Rainbow Index was associated with all the direct and indirect parameters in the model. For every one-unit increase in the Rainbow Index (starting at one and moving to 14), the discrimination score decreased by 12 points (95% CI [-11.96,-11.95]), internalized homonegativity by 0.00094 (95% CI [-0.000937, -0.000936]), the compulsive sexual behavior scores by 0.000064 (95% CI [-0.000064, -0.000063]), and the number of HIV exposures decreased by 0.000219 (95% CI [-0.0000294, -0.0000145]) (Table 8). For a one-unit increase in the Rainbow Index, the number of times a condom was used increased by 0.0017 (95% CI [0.0017, 0.0018]), and the number of sexual partners increased by 0.004 (95% CI [0.0029, 0.0056]) (Table 8). While the changing relationships are small they do provide evidence that the changing relationships are mutually influencing each other within the ABM to shape the emergence of HIV risk and diagnosis.

Table 8. Unadjusted associations of unstandardized beta estimates and 95% confidence intervals of policy and respective parameters

Policy (starts at 1 and goes to 14)	β	95% CI
# of sexual partners	0.004	(0.0029, 0.0056)
Discrimination score	-11.95	(-11.96, -11.95)
Internalized homonegativity	-0.00094	(-0.000937, -0.000936)
# of exposures	-0.000219	(-0.0000294, -0.0000145)
Compulsive sexual behavior scores	-0.000064	(-0.000064, -0.000063)
# of times condoms used	0.0017	(0.0017, 0.0018)

Unadjusted associations of the Rainbow Index, parameters and HIV serostatus

In unadjusted logistic regression analyses for every one-unit increase in the Rainbow Index, the odds of an HIV positive serostatus increased by 1.00 [95% CI (1.00, 1.00)], which was not significant because the confidence interval is at one (Table 9). This was the same relationship found for the number of sexual partners and the discrimination score. As the homonegativity score increased by one in the unadjusted analyses, the odds ratio of HIV positive serostatus was 0.91 [95% CI (0.79, 1.04)]. However, the confidence interval included one. Interestingly, in the unadjusted model a one-unit increase in compulsive sexual behavior decreased the odds of HIV positive serostatus [OR=0.85, 95% CI (0.76, 0.85)]. When condoms were used, the odds of HIV positive serostatus was reduced [OR=0.96, 95% CI (0.96, 0.96)].

Table 9. Unadjusted odds ratios and 95% confidence intervals of parameters and HIV positive serostatus

	HIV positive status	
Variable	**OR**	**95%**
Policy (Rainbow Index)	1.00	(1.00, 1.00)
Discrimination score	1.00	(1.00, 1.00)
Homonegativity score	0.91	(0.79, 1.04)
# of desired sexual partners (direct relationship)	1.00	(1.00, 1.00)
# of sexual encounters	0.96	(0.96, 0.96)
Compulsive sexual behavior (direct relationship)	0.85	(0.76, 0.95)
Condom use (direct relationship	0.96	(0.96, 0.96)

Unadjusted associations between parameters linked in the agent-based model

In the unadjusted linear regressions exploring relationships between the ABM parameters, all of the parameters were significantly associated with each other. For every one-unit increase in the discrimination score, the internalized homonegativity score increased by 0.000068 [95% CI (0.00007, 0.00007)] (Table 10). Once more these findings align with the goal of aim two to assess the changing relationships between simulated parameters.

Table 10. Unadjusted association between unstandardized discrimination scores and internalized homonegativity scores

	Internalized Homonegativity Score	
	β	**95% CI**
Discrimination scores	0.000068	(0.0000676, 0.0000678)

Internalized homonegativity was associated with the four other parameters within the ABM's conceptual model (i.e., the desired number of sexual partners, number of sexual encounters, compulsive sexual behavior, and condom use). For a one-unit increase in the internalized homonegativity score, the number of preferred sexual partners was decreased by 0.99 [95% CI (-1.82, -0.17)] (Table 11). For every one-unit increase in internalized homonegativity, the number of sexual encounters in the ABM increased by 9.7 partners [95% CI (9.64, 9.72)] (Table 11). Compulsive sexual behavior scores increased by 0.21 [95% CI (0.21, 0.21)] for each unit increase in the internalized homonegativity score (Table 11). In the unadjusted Poisson regressions, for a one-unit increase in the internalized homonegativity score the number of sexual encounters and the number of times a condom was used increased by 4.07 [95% CI (4.06, 4.08)].

Table 11. Unadjusted linear regression results of unstandardized internalized homonegativity scores beta estimates and other ABM parameters

	Preferred number of sexual partners	
	β	95% CI
Internalized homonegativity	-0.994	(-1.82, -0.17)
	Number of sexual encounters	
Internalized homonegativity	9.68	(9.64, 9.72)
	Compulsive sexual behavior	
Internalized homonegativity	0.21	(0.21, 0.21)
	Number of times condoms used	
Internalized homonegativity	9.50	(9.47, 9.54)

Table 12. Unadjusted Poisson regression models of unstandardized internalized homonegativity beta coefficients and count variables of the ABM

	Beta	95% CI
	Number of sexual encounters	
Internalized homonegativity	4.07	(4.06, 4.08)
	Number of times condom used	
Internalized homonegativity	4.07	(4.06, 4.08)

Adjusted associations between HIV serostatus and parameters

Across all models (model one through five), the relationship between the number of times a condom was used and the reduction in the odds of being HIV seropositive remained relatively stable [ORs 0.93-0.97] (Table 13). Similarly, the number of desired sexual partners was not significant as the confidence intervals included one across all models. In model one, for every one-unit increase in the compulsive sexual behavior score, the odds of an HIV positive serostatus increased by 3.1 [95% CI (2.79, 3.51)]. In model two, for every one-unit increase in internalized homonegativity, the odds of an HIV positive serostatus increased by 1.27 [95% CI (1.10, 1.46)].

However, in model two, the relationship between compulsive sexual behavior and HIV positive serostatus was attenuated [OR=3.0, 95% CI (2.71, 3.41)].

When the discrimination score was added in model three, the discrimination score and the odds of an HIV positive serostatus was one [95% CI (1.00, 1.00)], which was not significant. This relationship remained the same in models four and five. In models, three through five, the odds ratio between internalized homonegativity and HIV positive serostatus was attenuated and non-significant. However, in model three, the compulsive sexual behavior odds ratio was amplified. With every one-unit increase in the compulsive sexual behavior score, the odds of an HIV positive serostatus increased to 7.31 [95% CI (4.80, 11.13)], indicating the dynamic and interactional nature of the emergence of HIV risk. This was four points higher than in model two.

In model four, I included the policy parameter. Condom use was significant, as described earlier. However, the compulsive sexual behavior score's relationship with HIV positive serostatus was attenuated yet still statistically significant [OR=6.02, 95% CI (3.92, 9.24)]. Lastly, for every one-unit improvement in the policy, the odds of an HIV positive serostatus was 0.99 [95% CI (0.993, 0.997)]. A policy change from one to 14 would accumulate to a reduced odds of HIV positive serostatus by 14.

In the final model five, the number of sexual encounters was included. The protective effect of using condoms was reduced by 0.4 to 0.97 [95% CI (0.96, 0.98)] vs. 0.93-0.94 in previous models. The odds ratio of compulsive sexual behavior to HIV positive serostatus increased to 6.52 [95% CI (4.24, 10,01)]. The number of sexual encounters reduced the odds of an HIV positive serostatus by 0.97 [95% CI (0.96, 0.97)], which may indicate that in the ABM **who** an agent has sex with (i.e., HIV positive vs. negative agent) rather than simply the frequency of sexual partners may be more important.

Table 13. Forward stepwise logistic regression of HIV positive serostatus and ABM parameters

	HIV positive serostatus	
Variable	**OR**	**95% CI**
Model 1		
Condom use	0.94	(0.90, 0.94)
Compulsive sexual behavior score	3.13	(2.79, 3.51)
# of desired sexual partners	1.00	(1.00, 1.00)
Model 2		
Condom use	0.94	(0.94, 0.94)
Compulsive sexual behavior score	3.04	(2.71, 3.41)
# of desired sexual partners	1.00	(1.00, 1.00)
Internalized homonegativity score	1.27	(1.10, 1.46)
Model 3		
Condom use	0.93	(0.92, 0.93)
Compulsive sexual behavior score	7.31	(4.80, 11.13)
# of desired sexual partners	1.00	(1.00, 1.00)
Internalized homonegativity score	1.12	(0.81, 1.54))
Discrimination score	1.00	(1.00, 1.00)
Model 4		
Condom use	0.93	(0.92, 0.93)
Compulsive sexual behavior score	6.02	(3.92, 9.24)
# of desired sexual partners	1.00	(1.00, 1.00)
Internalized homonegativity score	1.10	(0.79, 1.51)
Discrimination score	1.00	(1.00, 1.00)
Policy	0.99	(0.993, 0.997)
Model 5		
Condom use	0.97	(0.96, 0.98)
Compulsive sexual behavior score	6.52	(4.24, 10.01)
# of desired sexual partners	1.00	(1.00, 1.00)
# of sexual encounters	0.97	(0.96, 0.97)
Internalized homonegativity score	1.08	(0.78, 1.50)
Discrimination score	1.00	(1.00, 1.00)
Policy	0.99	(0.993, 0.997)

Discussion

In the ABM, HIV risk is an emergent process that arises from complicated relationships and stochastic processes of interacting parameters. When the "policies" in the model were more stigmatizing, GBMSM agents' experiences of discrimination heightened, which increased homonegativity that, in turn, increased compulsive sexual behavior in the model. These findings show that the relationships between the parameters can create considerable implications for the emergence of HIV risk behaviors and diagnoses among the GBMSM agents in Europe. The ABM suggests that stigmatizing policies play an upstream role in shaping the relationships between discrimination, mental health and sexual behaviors that shape GBMSM's HIV risk in Europe.

The ABM had some interesting findings related to the compulsive sexual behavior score and its relationship to HIV serostatus. In the unadjusted model, as compulsive sexual behavior increased it reduced the odds of HIV positive serostatus. However, the compulsive sexual behavior score became the most significant factor associated with an HIV positive serostatus when "adjusting" for the other parameters in the model. The changing relationship provides credence to the interactional and dynamic nature that shapes the emergence of HIV risk among GBMSM in the model. A systematic review found that compulsive sexual behaviors cooccurs with numerous other factors such as depression or anxiety (Yoon et al., 2016). In this ABM, as the other variables were added into analyses, compulsive sexual behavior's relationship to HIV serostatus changed. In addition, the number of sexual encounters did not increase the odds of an HIV positive serostatus. This reverse relationship could be because as the ABM progressed most of the agents had an HIV negative or undetectable, which means that most sexual interactions were occurring between negative or undetectable agents—and thus transmission of HIV was reduced. It may also indicate that HIV status of the sexual partner is more important rather than just the frequency of

sexual partners in shaping HIV risk. Together, these findings portray the dynamic role that stigma plays in shaping the emergent effect of the interacting risk factors that influence HIV, rather than simply examining the relationship between individual parameters and HIV. This proof of concept (aim two) identifies that HIV research could be enhanced by focusing on examining how the system of dynamic relationships and interactions of various risk factors can influence HIV diagnosis.

ABMs are being used more to understand how diverse stochastic processes can influence populations' collective health outcomes. An ABM that looked at combination HIV prevention efforts indicated that both increases in HIV testing and increases in viral suppression are needed to reduce new HIV diagnoses by 25% in the United States (Gopalappa et al., 2017). In Gopalappa's model, if 85% of HIV diagnoses are detected, then it would require that 78% of persons achieve viral suppression to reduce new infections by 25% (Gopalappa et al., 2017). If 90% of HIV cases were diagnosed, then 81% of persons would need to achieve viral suppression. This dissertation chapter adds to the growing body of ABM-based research showing how multiple intersecting factors can either reduce or elevate HIV risk and diagnosis.

Research identifies stigma as an important factor related to elevated HIV risk and infection globally (Hylton et al., 2017; Lunze et al., 2017; Mimiaga et al., 2015, 2019; Pachankis et al., 2017a; Restar et al., 2020; Stojanovski et al., 2019). Stigma operates across multiple domains. For example, HIV stigma may limit HIV testing. Moreover, gay-related stigma can activate poorer mental health, which itself is related to sexual behavior changes. In a feedback loop, anti-gay related stigma, HIV-related stigma, and mental health stigma can, in concert, serve to further alienate GBMSM and activate poor mental health and at-risk sexual behavior pathways. Despite the multifaceted factors related to HIV, there are few studies that model the emergent outcomes of

the policy and social processes that underly the HIV risk environment. Researchers have called for improved scholarship to understand the more upstream causes of poor health (Diez Roux, 2011; Vaughan & Galea, 2017; Zaslavsky et al., 2019). The use of complex systems theory and ABM in this dissertation chapter offers powerful analytic approaches to model upstream factors that shape and manipulate downstream behaviors. As Aristotle said, "…the totality is not, as it were, a mere heap, but the whole is something besides the parts…" (Aristotle & Ross, 1924).

Limitations and future research

As with all studies, there are limitations. The biggest challenge with ABM's are the decisions made for the mathematical equations and loops of code that govern the rules of the model. Starting values of the parameters, including the environment, frequency of gay or non-gay agents, and movement within the environment can all influence the emergence of HIV in the ABM. In addition, moving forward or backward in time (policy 14 to one vs. one to 14) could influence the collective outcomes. Moreover, not every gay agent in the ABM will respond the same way to stigmatizing policies, and thus will not have the same homonegativity and sexual behavior changes. I attempted to address this by allowing probabilistic variation in alterations to internalized homonegativity and sexual behaviors. For example, while I used published literature to connect relationships between variables—I also allowed a chance to exist that the relationships could fall outside the 95% confidence intervals. Allowing variations in "chance" to occur ensures the model is not overfit and supports the model's quality and plausibility. Unfortunately, such probabilistic variation also creates "noisy" data. Future iterations of the algorithm and simulations will include sensitivity analyses to explore how variation in the initialized (starting) values of the parameters could influence the model's outcomes. The use of cross-impact balance analyses could further enhance the model and its parameters. Cross-impact balance analyses attempt to elucidate which

factors in a system are most critical to be incorporated within a model (Weimer-Jehle, 2006). Cross-impact balance analyses include the participation of multiple experts to identify the parameters and relationships between parameters and helps to study interdisciplinary factors that are related with one another. Moreover, participatory systems mapping exercises with communities of GBMSM could help to further understand the real world lived experiences. Use of these methods could help to advance system science approaches to study HIV inequities.

Another limitation is the use of the HIV undetectable status. This late addition to the algorithm reduced the level of HIV "infection." While it should be included, it might add too much complexity at this early stage of the algorithm. To improve this ABM for future work, I propose to remove the HIV undetectable status. With the removal, it would allow for more interaction with virally unsuppressed agents. In future iterations of the ABM, I will introduce additional variability by allowing viral suppression rates to take on different percentages (e.g., 0-90% viral suppression rates). I will incorporate a new infection parameter in the analytic dataset, which would improve assessments of causality in the model.

This ABM had a low number of gay-gay agent interactions and a low number of sexual acts that occurred. The use of an open environment and reduced "movement" of agents within the model limited the number of interactions. In a future improved version of the ABM, I plan to incorporate a social network structure, which is supported by the literature (McCree et al., 2013; Montealegre et al., 2013; Yang et al., 2020). I will explore whether additional or fewer simulations are needed to capture the emergent effects.

Lastly, the data produced is based on simulated data. Therefore, the model is not representative of what occurs in the real world. It should only be interpreted within the confines of the model. The ABM's goal was to generate hypotheses that can be tested in the future, rather

than hypothesis testing. Although the simulated data is not real-world, it is informed by real-world processes and statistical estimates from the literature. The strength of the proposed methods allows for understanding how HIV infection emerges from structural-level issues, which are complex.

Conclusion

In this ABM, numerous interacting and overlapping systems and processes structured by stigmatizing policies negatively influence GBMSM agent's capacities to avert HIV risk and diagnosis. The ABM indicates that HIV risk and diagnosis emerges from a complex web of relationships such as policies, discrimination, mental health, and sexual behaviors. To fully address HIV risk, research on the ecosystem of risks, and not solely on the individual parts, can enhance HIV prevention and interventions.

Chapter 4. Interactional Effects of Stigmatizing Policies, Mental Health, and Sexual Behaviors Influence HIV Diagnoses Among European Gay, Bisexual, and Other Men Who Have Sex With Men

Abstract

Structural stigma shapes GBMSM's mental health and sexual behaviors and can serve to elevate their risk of HIV diagnosis. The aim of this study was to examine how stigmatizing policies interact with downstream anxiety/depression and sexual behaviors to socially pattern HIV disparities among GBMSM in Europe. I conducted a secondary data analyses of the European Men who have sex with men Internet Survey (EMIS) from 2017. Participants were recruited for the EMIS-2017 study via social media, geolocation applications, and non-governmental organizations. A total of 126,261 participants living in 39 European countries were sampled. I used the Rainbow Index, a score given to countries based on their SGM policies, as the predictor and self-reported HIV serostatus as the outcome. I conducted adjusted random intercept and slope multi-level logistic regressions. I included interaction terms between the Rainbow Index, number of condomless sexual partners in the last year, and depression/anxiety. The main statistical analyses were the calculation of the predictive probability—which measures the probability of an HIV positive serostatus based on all the variables modelled. In the adjusted models, a one-unit improvement in the Rainbow Index, reduced the odds of HIV positive serostatus by 0.98 (95% CI (0.98, 0.99)). As the Rainbow Index improved, the predictive probability of an HIV positive

serostatus was reduced, regardless of condomless sex frequency. The predictive probability of an HIV positive serostatus also decreased, regardless of severity of anxiety/depression, as the Rainbow Index improved. However, GBMSM with a "severe" mental health score experienced a smaller rate of change. Country-level policies interact with downstream sexual behaviors and anxiety/depression to influence an HIV positive serostatus among GBMSM in Europe. These findings contribute to the accumulating evidence that stigmatizing policies can shape HIV inequity in Europe and must be taken into account when conceptualizing HIV risk.

Introduction

In this chapter, I further explore how stigmatizing policies influence HIV serostatus in Europe using empirical data to test the hypotheses generated from the agent-based model in aim two. This chapter builds on what I learned from the Complex Systems Theory visualization and ABM analyses by exploring how policies interact with downstream health behaviors and anxiety/depression to shape the emergence of GBMSM's self-reported HIV serostatus using real-world data.

Population-level inequities in HIV continue to exist globally, despite advances in prevention and treatment. In the WHO European Region, HIV incidence increased by 9% from 2010-2019 (European Centre for Disease Prevention and Control, 2020). However, the increase is largely driven by trends in Eastern and Central European countries. In Eastern Europe, the incidence rate increased by 23% from 2010-2019 (33.9 per 100,000 in 2010 to 41.7 in 2019) (European Centre for Disease Prevention and Control, 2020). In Central Europe, the incidence rate increased by 113% from 1.6 cases per 100,000 to 3.4 cases per 100,000. In Western Europe, incidence decreased by 24% from 7.5 cases per 100,000 people to 5.7 cases per 100,000 people (European Centre for Disease Prevention and Control, 2020). In 2019, 70% of newly diagnosed HIV cases (n=136,449) were from the Eastern Region, 16% from the West, and 5% from Central Europe (European Centre for Disease Prevention and Control, 2020). The rate of new diagnoses in Eastern Europe is eight times higher than the West and 12 times higher than in Central Europe (European Centre for Disease Prevention and Control, 2020).

While the rates are alarming, GBMSM in Europe experience elevated HIV inequities. Male-to-male sexual contact is the second highest transmission route in the entire European continent (European Centre for Disease Prevention and Control, 2020). However, variation exists

depending on the region or country in which GBMSM reside. In the European Union/European Economic Area, sex between men is the main route of HIV transmission, accounting for 39% of all incident cases in 2019 (European Centre for Disease Prevention and Control, 2020). Sex between men accounted for more than 60% of incident HIV cases in 10 countries—Croatia, Czechia, Germany, Hungary, Iceland, the Netherlands, Poland, Slovakia, Slovenia and Spain—when the mode of transmission was known (European Centre for Disease Prevention and Control, 2020). There were large increases in Bulgaria, Cyprus, Estonia, Lithuania, Poland, Romania and Slovakia in recent years (European Centre for Disease Prevention and Control, 2020). Additionally, in Central Europe, the male-to-female ratio was 5.5 times higher than in West and East, indicating the elevated HIV risk men experience in the Centre (European Centre for Disease Prevention and Control, 2020). These statistics portray the higher risk of HIV that GBMSM contend with in Europe.

Stigma that interacts across multiple domains, such as policies, interpersonal discrimination, and discriminatory healthcare services may perpetuate HIV risk among GBMSM. Stigma is posited as a fundamental cause of poor health (Hatzenbuehler et al., 2013). Stigma can shape HIV risk and diagnoses in Europe. In one European-wide study, anti-gay and anti-immigrant stigma in the countries to which GBMSM migrate is associated with reduced knowledge about prevention and condom usage (Pachankis, Hatzenbuehler, Berg, et al., 2017a). A study in Barcelona (Spain), Bratislava (Slovakia), Bucharest (Romania), Ljubljana (Slovenia), Prague (Czechia), and Verona (Italy) found that gay-related stigma was associated with elevated odds of sex under the influence of alcohol, cannabis, and other substances—all known as risk factors for HIV (Lelutiu-Weinberger et al., 2019). In the same study, a one standard deviation increase in stigma was associated with an 11% higher odds of having sex without a condom (Lelutiu-

Weinberger et al., 2019). A study in 14 European countries across the continent found that PLHIV who experienced discrimination in healthcare settings had more safer sex needs (Nöstlinger et al., 2014) As additional examples, stigma challenges the sexual health of GBMSM in other nations, such as Bosnia & Herzegovina, Croatia, the Netherlands, North Macedonia, and Serbia (Baros, 2018; Kamenov et al., 2016; Stojanovski et al., 2015; Stojanovski et al., 2019; Stojisavljevic et al., 2017; van Opstal et al., 2018). These diverse geographic studies indicate that stigma plays a role in the social patterning of HIV risk and diagnosis among European GBMSM.

Stigma also shapes intermediary factors that influence HIV risk and infection. Global research portrays how GBMSM's mental health inequities are socially patterned due to stigmatization (Burton et al., 2019; Hatzenbuehler, 2009; Jeffries IV et al., 2013; Kamenov et al., 2016; Pachankis, 2015; Pachankis et al., 2015; Stojanovski et al., 2018; Zhou et al., 2019). Research indicates that poor mental health reduces the likelihood of condom use during sex, increased utilization of substances, and increased frequency of sexual partners; all considered risk factors for HIV (Mimiaga et al., 2015; Pachankis, Hatzenbuehler, Berg, et al., 2017a; Ross et al., 2013). A study in France, Germany, Italy, and the United Kingdom indicated that depression was associated with reduced adherence to HIV treatment among PLHIV (Akinwunmi et al., 2021).

Global, country and local-level policies have a role in inducing stigma, shaping mental health, and, ultimately, HIV risk and diagnosis. For example, GBMSM in St. Petersburg, Russia, surveyed after the passage of the local anti-gay "propaganda" ordinance (March 2012) had a 1.7-fold greater likelihood of depression, as compared to GBMSM surveyed before the ordinance (Hylton et al., 2017). Additionally, among GBMSM who experienced stigma, depression was three times greater [AOR=2.92, 95% CI (2.02-4.24)] (Hylton et al., 2017). The European Centres for Disease Prevention and Control found that two-thirds of government health representatives in

Europe and Central Asia reported stigma and discrimination among key populations as barriers to HIV testing (European Centre for Disease Prevention & Control, 2017). Further research is needed to identify the pathways in which stigma interacts with other factors to shape the emergence of HIV risk and diagnosis.

In this dissertation chapter, I aim to estimate the extent to which country-level policy variations interact with downstream health behaviors and anxiety/depression to influence self-reported HIV prevalence among European GBMSM. I hypothesize that stigmatizing policies will positively interact with mental health and sexual behaviors to elevate the probability of HIV diagnoses. This hypothesis was generated from the findings that HIV emerges from interacting factors in the visualization and ABM (Chapter two and three).

Methods

I used data from the global European Men Who Have Sex With Men Internet Survey (EMIS-2017) conducted in 2017. EMIS-2017 included all European nations and some non-European countries, for example, Lebanon, Israel, Canada. The final questionnaire had 409 items that included questions in the following areas: demographics; morbidities (including violence/abuse and mental health); sexual and drug-using behaviors, including HIV testing, condom use, PrEP, PEP; unmet needs; and knowledge and utilization of interventions. The Observational Research Ethics Committee at the London School of Hygiene and Tropical Medicine approved the original study. The London School of Hygiene and Tropical Medicine and the University of Michigan developed an agreement granting permission for use of the data for analyses.

Survey administration and sampling

The survey was administered in 2017 in 46 countries across the world and was translated into 33 languages. EMIS-2017 promoted the survey on national and trans-national commercial, non-governmental, gay, and SGM websites; social networking sites (e.g., Facebook); and geo-spatial sexual contact applications (apps) and websites (e.g., Planet Romeo, Grindr). A total of 144,259 MSM were reached, of which 139,173 provided consent to participate (96% response rate). Of these, 137,358 (99%) met eligibility criteria (i.e., identified as male gender, lived in a qualifying country, participated in male-to-male sexual activity, and were over the age of sexual consent in the respective country of residence). Additional methodology of the survey sampling and administration has been previously published (Weatherburn et al., 2019).

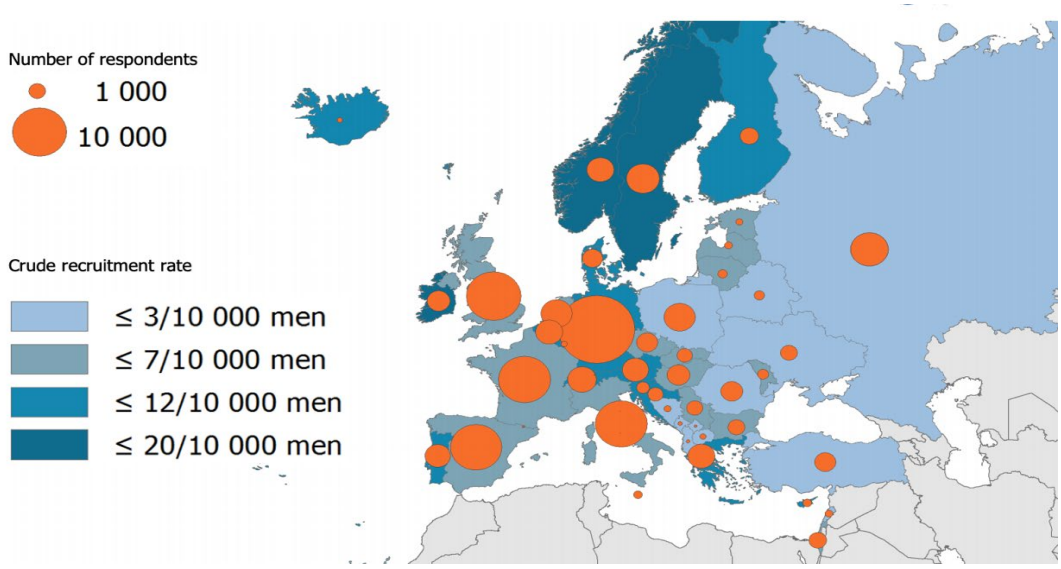
Among the sample, there were a total of 126,261 participants that resided in Europe, as defined by the European World Health Organization Region (Kluge, 2020). EMIS-2017's goal was to reach a minimum sample size of 100 per country. The sample sizes in Albania, Kosovo, and Montenegro were less than 100 (n=171 summative total across the three countries). EMIS-2017 collapsed these countries into one because of the small samples in each country. Given that the observations were collapsed into one, linking the Rainbow Index was impossible, thus, I excluded these observations from the analyses. Figure 5 provides information on the crude response rates by country. As a result, the sample size for my European-centric secondary analysis was 126,090. Table 14 outlines the countries I included in the analyses. Translations included 23 out of the 24 official European Union languages (excluding Gaelic Irish) and an additional six European languages (Albanian, Norwegian, Macedonian, Russian, Turkish, and Ukrainian). The survey was also translated into Arabic, the predominant language of migrants into Europe since 2014.

Table 14. European countries included for analysis

Albania	Austria	Bosnia & Herzegovina	Belarus
Belgium	Bulgaria	Croatia	Cyprus
Czechia	Denmark	Estonia	Finland
France	Germany	Greece	Hungary
Iceland	Ireland	Italy	Kosovo
Latvia	Lithuania	Luxembourg	Malta
Moldova	Montenegro	Netherlands	North Macedonia
Norway	Poland	Portugal	Romania
Russia	Serbia	Slovakia	Slovenia
Spain	Sweden	Switzerland	Turkey
Ukraine	United Kingdom		

The University of Michigan Health and Behavioral Sciences Institutional Review Board reviewed and categorized this secondary analysis as exempt, given that there were no personal identifiers (including no IP addresses) in the dataset.

Figure 5. Crude rate of respondents in the European continent by country (n=126,090)



Source: 1 European Men who have Sex with Men Internet Survey 2017

Variables

Outcome variables

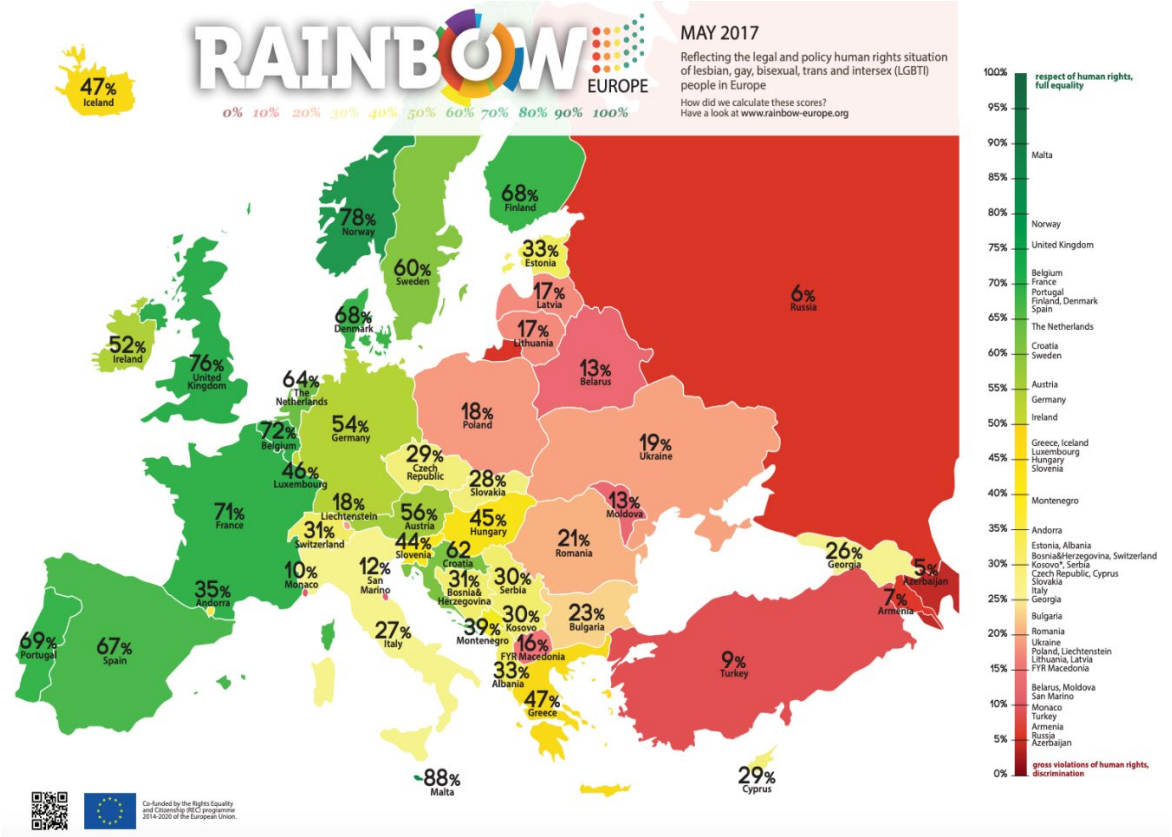
The primary outcome variable was self-reported HIV serostatus, which I dichotomized as HIV positive or negative. I excluded those who reported never having an HIV test (n=27,409) from the serostatus analysis. Among those who reported never testing, zero reported an HIV positive serostatus. Thus, my final sample size for the HIV serostatus outcome analyses was 98,600.

Given that a large number of participants reported never having tested and the significant body of research showing stigma's role as a barrier to HIV testing, I conducted supplementary analyses of a secondary outcome, HIV testing, defined as ever tested or never tested. I conducted bivariate analyses for this outcome to support interpretation of the HIV serostatus results given the focus of the dissertation was on exploring HIV risk rather than testing. The sample size for secondary HIV testing outcome was 125,790.

Explanatory variables

I used the Rainbow Index to assess country-level stigmatizing policies. The International Lesbian, Gay, Bisexual, Transgender, and Intersex Association of Europe developed the index (ILGA Europe, 2018). As described in Chapter 3 (pp. 103), the index ranks countries based on their policies that afford rights and protections to lesbian, gay, bisexual, transgender, and queer (LGBTQ+) persons. Briefly, the Rainbow Index includes policies such as the right to marriage, anti-discrimination legislation, to name a couple. The index weights specific policies more than others. For example, anti-discrimination and protection legislation accounts for 25% of the score a country receives. I used the Rainbow Index from 2017 to match the year of the data collection. For 2017, the Rainbow Index ranged from 6-88 (theoretical range 0-100). Each country's score can be found in Figure 6.

Figure 6. Rainbow Index scores for each European country, 2017



Source: 2 International Lesbian, Gay, Bisexual, Transgender and Intersex Association of Europe, 2017

I also included explanatory variables measured in the EMIS-2017 survey. The first was a combined anxiety/depression four-item scale (measured by the Patient Health Questionnaire (PHQ-4)), with a total possible range from zero (normal) to 12 (severe). The final explanatory variable was the number of non-steady sexual partners in which a condom was not used. The non-steady sexual partners variable was ordinal and ranged from zero (zero), 1-10 (one), 11-20 (two), to 51+ partners (six).

Covariates

I included six confounder variables. The first was financial stability, which was a 5-point Likert scale that ranged from one (really comfortable on current income) to five (really struggling

on current income). Secondly, sexual identity, which was defined as gay, bisexual, or other. Third, education, which was categorized as less than high school, high school diploma, bachelor's degree, or graduate degree. Fourthly, I included a 3-point Likert outness variable ranked as one (out to none/few), two (out to some), and three (out to almost all). The fifth covariate was an abuse variable, which ranged from zero (have never experienced intimidation, assault, or harassment) to three (experienced intimidation, assault, and harassment). Last was age, included as a continuous variable. Settlement size was an important variable to include, given that one's city or town's size can alter the people with whom GBMSM interact and, thus, alter potential exposure to HIV. The settlement size variable is categorized as follows: (1) a million or more people; (2) 500,000-999,999 people; (3) 100,000-499,999 people; (4) 10,000-99,999 people; (5) less than 10,000 people. I also included the country in which GBMSM resided as another covariate, given that this would also influence potential exposure to HIV.

Statistical analyses

I used univariate analyses to understand the sample's descriptive information, including geographic areas of residence in Europe, frequencies and percentages of sociodemographics, depression/anxiety, sex without a condom, HIV testing, and HIV serostatus. I determined means and standard deviations for normally distributed continuous variables and medians and ranges for non-normally distributed continuous variables. Next, I conducted bivariate analyses to understand the associations between sociodemographic, explanatory variables, and confounders with the outcome of self-reported HIV serostatus using chi-square measures of association ($p<0.05$ was used to determine statistical significance).

Given the nested nature of the data of participants (level-one) within cities/towns (level-two) within countries (level-three), I utilized a random intercept and slope multilevel logistic

regression model. The level-one variables included the explanatory variables, other covariates, and the outcome variable of self-reported HIV serostatus. The level-two variable was the settlement (city) size, and the level-three variable was the country in which GBMSM resides. Given the outcomes' binary nature, I employed multilevel logistic regression models to test the association between the Rainbow Index of the country and an individual's self-reported HIV serostatus (dichotomized as tested & diagnosed positive or tested & diagnosed negative, n=98,600).

I created two multi-level models. The first was a basic model with each covariate or explanatory variable serving as its own variable in the model. In the second, I created an interaction term between the Rainbow Index (a level-3 variable) and two downstream explanatory variables, anxiety/depression and condomless anal sex with non-steady partners (level one variables). The multilevel models explored how HIV serostatus varied by the Rainbow Index, taking into account the clustering of cities within countries. I adjusted for all the covariates described above because they were significant in bivariate analyses ($p<0.05$) and have been identified as salient factors in the research literature. I report adjusted odds ratios (OR) and corresponding 95% confidence intervals (CI) for the multi-level models.

The main statistical analyses of interest for aim three are the predictive probabilities, which are calculated using the multi-level model. For these analyses, I graphed the predictive probabilities of a self-reported HIV positive serostatus by the Rainbow Index and their interaction with anxiety/depression and condomless anal sex with non-steady partners while also adjusting for other variables. *The predictive probabilities estimate the chance of being HIV positive based on all the variables included within the model, which aligns with the complex systems approach used in this dissertation*. I analyzed the data using Stata 16 (StataCorp, 2016).

While the total sample size for the HIV serostatus outcome was 98,600, the analytic sample varied according to the missingness of the explanatory variables and covariates. A complete case methodology was used for the analyses, in line with other EMIS research (Pachankis et al., 2017b; Pachankis et al., 2017). The percentage missing of explanatory variables and covariates ranged from 0% to 4.5%. The condomless non-steady sex partners variable was missing for 4.5% of the sample (n=4,389) and anxiety/depression were missing for about 1.4% (n=1,412). The education and experiences of abuse variables had no missing data. The outness and the settlement size variables had 1% missing (n=1,027 and 1,095, respectively). The sexual orientation and financial stability variables had less that 1% missing (n=76 and n=340, respectively). Thus, with a complete case analysis approach, the analytic sample for the multivariable multi-level model of self-reported HIV serostatus was reduced to 90,884.

Results

Geographic findings

Of the 98,600 participants, the majority (85.5%, n=84,294) came from European Union member states. Participants in the European Free Trade Association (EFTA) states of Iceland Liechtenstein, Norway, Switzerland accounted for 5.3% (n=5,250) of the sample. Participants from Russia made up 5.4% (n=5,307) of the sample. The European Neighborhood Policy (ENP) countries—Belarus, Moldova, and Ukraine accounted for 1.7% (n=1,657) of the total sample. Lastly, 2.1% (n=2,092) of participants lived in the EU Enlargement area states—Bosnia & Herzegovina, North Macedonia, Serbia, and Turkey. The average Rainbow Index score was 50.8 (Stdev=21.5, Range: 6-88).

Sociodemographic results

The median age of respondents was 37 years of age (Stdev: 12.2) ranging from 14-100 years. The majority of respondents, 81% (n=80,146) reported that they were gay, 13% (n=12,686) bisexual, 6% (n=5,692) reported other, which included 1% stating straight (Table 15). The majority, 54% (n=52,781) had graduate degrees, 30% (n=29,533) had university degrees, 14% (n=13,277) had completed high school, and 4% (n=3,009) had less than high school. In terms of financial stability, 14% (n=13,532) stated they were really comfortable, 37% (n=36,647) said comfortable, 33% (n=32,394) said neither comfortable nor uncomfortable, 12% (n=11,350) were struggling, and 4% (n=4,337) stated really struggling. All sociodemographic variables were statistically significant and associated with HIV serostatus in bivariate analyses (Table 16).

Table 15. Frequencies and percentages of sociodemographic characteristics (N=98,600)

	N	%
Demographics		
Education		
No high school	3,009	3.5
High school	13,277	13.5
University	29,533	30.0
Graduate	52,781	53.5
Sexuality		
Gay	80,146	81.4
Bisexual	12,686	12.9
Other	5,692	5.8
Financial stability		
Really comfortable	13,532	13.8
Comfortable	36,647	37.3
Neither	32,394	33.0
Struggling	11,350	11.6
Really struggling	4,337	4.4

Table 16. Unadjusted chi-square measures of the associations between sociodemographics and self-reported HIV serostatus (n=98,600)

	Ever diagnosed with HIV (n=98,600)		
	Tested & Positive, N (%)	Tested & Negative, N (%)	p-value
Education			
No high school	560 (4.3)	2,449 (2.9)	0.000
High school	1,916 (14.7)	11,361 (13.3)	
University	3,930 (30.1)	25,603 (29.9)	
Graduate or more	6,653 (51.0)	46,128 (53.9)	
Financial stability			
Living really comfortably	1,681 (12.9)	11,851 (13.9)	0.000
Living comfortably	4,641 (35.7)	32,006 (37.5)	
Neither comfortable nor struggling	4,230 (32.5)	28,164 (33.0)	
Struggling	1,709 (13.1)	9,641 (11.3)	
Really struggling	747 (5.7)	3,590 (4.2)	
Sexuality			
Gay	11,686 (89.6)	68,460 (80.1)	0.000
Bisexual	830 (6.4)	11,856 (13.9)	
Other	522 (4.0)	5,170 (6.1)	

Explanatory variable results

Most of the respondents were out to almost all, 46% (n=44,744), 29% (n=28,482) were out to some, and 25% (n=24,347) were out to none or a few (Table 17). The mean PHQ-4 (one to four) score was 1.76 (Stdev=0.91). Most persons had a "normal" score on the PHQ-4, 49% (n=47,126), 34% had a "mild" score (n=32,906), 10% (n=10,099) had a "moderate" score, and 7% (n=7,057) had a "severe" score. Majority of participants, 57% (n=53,936) had zero condomless sexual partners in the last year, while 35% (n=33,294) stated they had sex with 1-10 non-steady partners without a condom, 4% (n=3,337) had 11-20 non-steady partners, 2% (n=1,401) had 21-30 non-steady partners, 0.6% (n=583) had 31-40 non-steady partners, 0.4% (n=357) had 41-50 non-steady partners, and 1.4% (n=1,303) had 51 or more non-steady condomless sex partners. All explanatory

variables were statistically significant in their associations with HIV serostatus in bivariate analyses (Table 18).

Table 17. Frequencies and percentages of explanatory variables (N=98,600)

Variable	N	%
Outness		
Out to few or none	24,347	25.0
Out to some	28,482	29.2
Out to almost all	44,744	45.9
Experiences of abuse		
None	30,686	31.1
1	16,945	17.2
2	34,745	35.2
3	16,224	16.5
# of condomless non-steady partners in last 12 months		
None	53,936	57.3
1-10	33,294	35.3
11-20	3,337	3.5
21-30	1,401	1.5
31-40	583	0.6
41-50	357	0.4
51+	1,303	1.4
PHQ-4		
Normal	47,126	48.5
Mild	32,906	33.9
Moderate	10,099	10.4
Severe	7,057	7.3

Table 18. Unadjusted chi-square measures of association of explanatory variables and self-reported HIV serostatus (n=98,600)

	Ever diagnosed with HIV (n=98,600)		
	Tested & Positive, N (%)	Tested & Negative, N (%)	p-value
Rainbow Index			
Low (poor policies)	3,647 (28.4)	24,685 (29.9)	0.000
Medium	3,303 (25.8)	22,244 (26.9)	
High (good policies)	5,872 (45.8)	35,638 (43.2)	
Numberless of condomless sex partners in last 12 months			
Zero	4,207 (34.0)	49,729 (60.8)	0.000
1-10	5,034 (40.6)	28,260 (34.5)	
11-20	1,299 (10.5)	2,038 (2.5)	
21-30	648 (5.2)	753 (0.9)	
31-40	298 (2.4)	285 (0.4)	
41-50	176 (1.4)	181 (0.2)	
51+	727 (5.9)	576 (0.7)	
PHQ4			
Normal	6,015 (46.9)	41,111 (48.7)	0.000
Mild	4,404 (34.3)	28,502 (33.8)	
Moderate	1,392 (10.9)	8,707 (10.3)	
Severe	1,018 (7.9)	6,039 (7.2)	
Experiences of abuse			
No experiences	3,788 (29.0)	26,898 (31.4)	0.000
One experience	2,096 (16.1)	14,849 (17.4)	
Two experiences	4,507 (34.5)	30,328 (35.4)	
Three experiences	2,668 (20.4)	13,556 (15.9)	
Outness level			
Out to nobody	2,227 (17.2)	22,120 (26.1)	0.000
Out to some	3,506 (27.0)	24,976 (29.5)	
Out to everybody	7,234 (55.8)	37,510 (44.3)	

Country-level stigma, condomless sex, and HIV serostatus

Among the 98,600 who reported having had an HIV test and HIV status, 13% (n=13,059) reported that they had an HIV positive serostatus, while 87% (n=85,541) reported a negative HIV serostatus. In the unadjusted multilevel model of self-reported HIV serostatus, the random effects intercept for the country (level-3) indicated that the probability of an HIV positive serostatus varied by 0.13 (13%, 95% CI (0.08, 0.21). In the multi-level model with country (level-3) and city size (level-2), the country-level (level-3) intercept varied by 12% (95% CI 0.07, 0.21) and for the city (level-2) nested within country, the intercept varied by 0.05 or (5%, 0.04, 0.08). In the unadjusted model with only the Rainbow Index as a predictor, for every one-unit increase in the Rainbow Index, the odds of an HIV positive serostatus was 1.00 (0.99, 1.01), which was not significant given the confidence interval included one. The country-level and city-level intercepts remained the same.

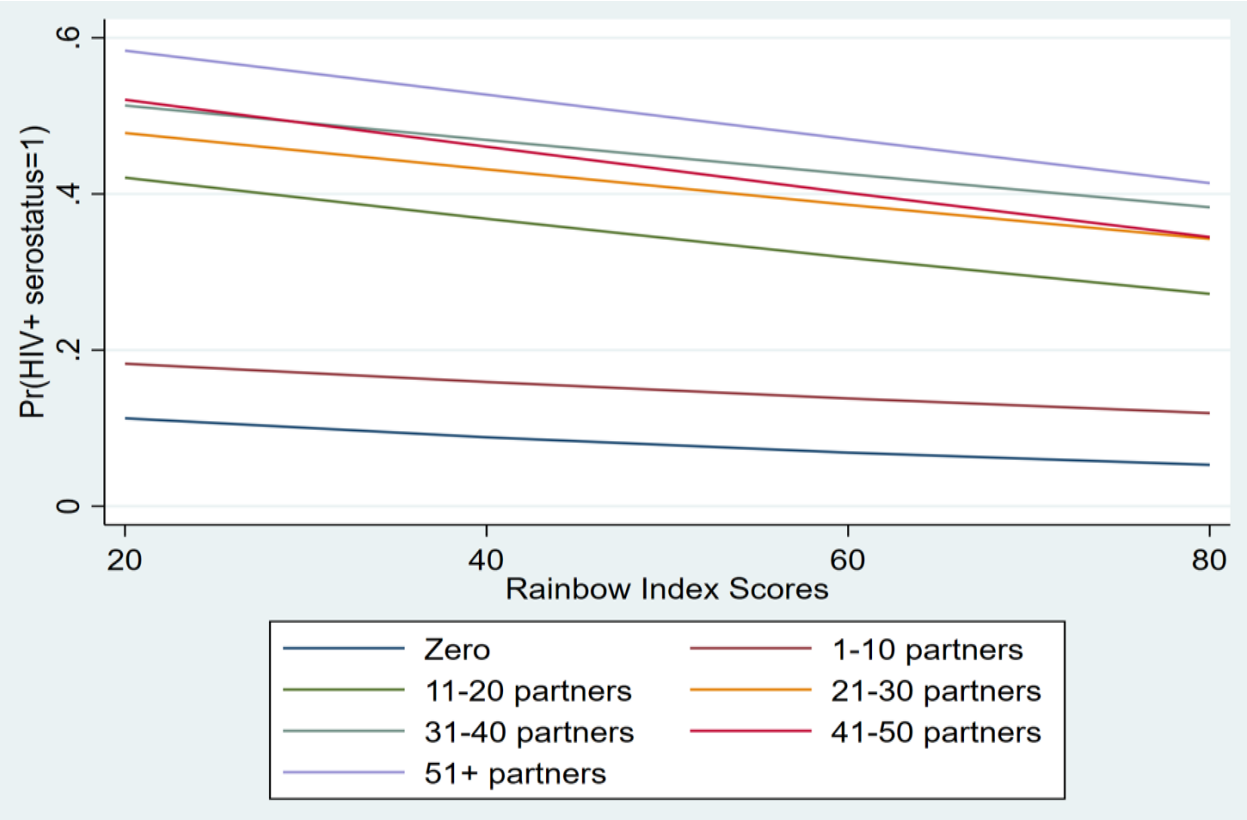
The adjusted multilevel model with no interaction terms (adjusted for age, sexuality, education, financial stability, abuse, mental health, outness, and the number of condomless sexual partners) indicated the country-level (level-3) variable's intercept value was 0.13 (95% CI 0.08-0.23), portraying a 13% variation in the odds of self-reported HIV positive serostatus depending on which country GBMSM lived in. The variation in HIV serostatus associated with the city's size (level-2) was reduced to 0.03 (3%, 95% CI (0.02, 0.06). For every one-unit improvement in the Rainbow Index, the odds of an HIV positive serostatus was 0.98 (95% CI (0.98, 0.99)), indicating that more protective policies reduce the odds of reporting an HIV positive serostatus, although the effect is small (Table 19).

Table 19. Adjusted odds ratios and 95% confidences intervals of HIV diagnosis from multi-level model (n=90,884)

	HIV Diagnosis	
	OR	**95% CI**
Rainbow Index	0.98	(0.98, 0.99)
# of condomless sex partners (none=referent)		
1-10 partners	2.16	(2.07, 2.26)
11-20 partners	7.23	(6.67, 7.85)
21-30 partners	10.03	(8.93, 11.29)
31-40 partners	12.08	(10.11, 14.43)
41-50 partners	10.91	(8.74, 13.61)
51+ partners	14.94	(13.22, 16.87)
PHQ4 (normal=referent)		
Mild	1.16	(1.11, 1.22)
Moderate	1.29	(1.19, 1.37)
Severe	1.35	(1.24, 1.47)
Outness (out to none=referent)		
Out to some	1.29	(1.21, 1.38)
Out to almost all or all	1.62	(1.52, 1.73)
Abuse (none=referent)		
Physical abuse	0.95	(0.89, 1.02)
Physical abuse + intimidation	0.96	(0.91, 1.01)
Physical, verbal abuse + intimidation	1.08	(1.01, 1.15)
Age	1.05	(1.04, 1.05)
Financial stability (really comfortable=referent)		
Living comfortably	1.07	(1.00, 1.15)
Neither comfortable nor uncomfortable	1.12	(1.05, 1.20)
Struggling	1.31	(1.20, 1.42)
Really struggling	1.48	(1.32, 1.65)
Education (less than high school =referent)		
High school	0.89	(0.79, 1.01)
University	0.82	(0.73, 0.92)
Master+	0.72	(0.64, 0.80)
Sexuality (gay=referent)		
Bi	0.51	(0.47, 0.56)
Other	0.72	(0.65, 0.81)
Country (level-3)	0.13	(0.08, 0.23)
City size (level-2)	0.03	(0.02, 0.06)

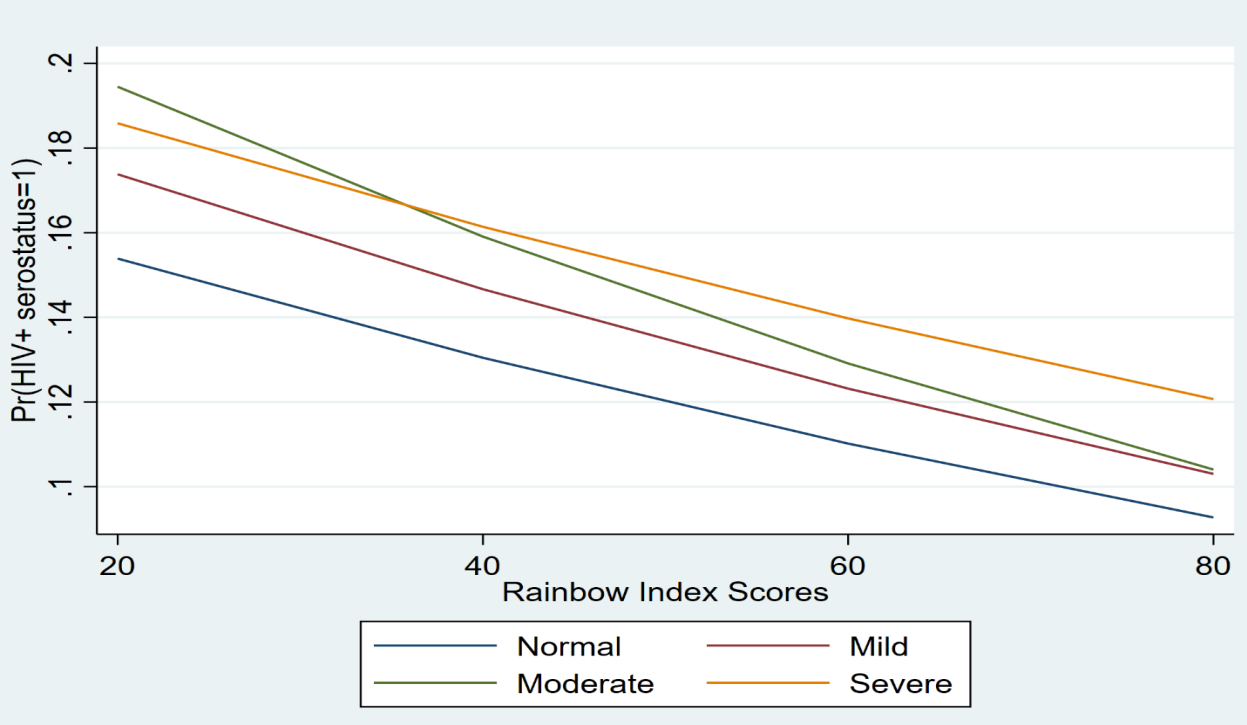
In the multivariable interaction models, the predictive probability (the main analysis of interest) of self-reported HIV positive serostatus changed with the Rainbow Index score of the country in which GBMSM reside across the two explanatory variables of interest. With higher Rainbow Index scores (better policies), the predictive probability of an HIV positive serostatus was reduced, regardless of condomless sex frequency with non-steady partners (Figure 7). However, the predictive probability of an HIV positive serostatus varied according to the interaction of policy and frequency of condomless non-steady sexual partners. GBMSM with a lower number of partners had lower starting predictive probability of an HIV positive serostatus, which further decreased with higher Rainbow Index scores. The rate of change (slopes) also varied by the frequency of condomless non-steady sexual partners that participants had. The predictive probability of an HIV positive serostatus was reduced more for GBMSM with a higher frequency of condomless non-steady sexual partners as the Rainbow Index scores got higher. As one example, participants with 51+ condomless sexual partners in the last year (purple line in Figure 7) who lived in a country with a Rainbow Index score of 20 (low protections) would have a 60% chance of having HIV. However, if the same participant lived in a country with a Rainbow Index score of 80 (high protections) the probability they had HIV was 40%, accounting for a 20% difference despite having the same sexual risk behaviors.

Figure 7. Predictive probability of self-reported HIV positive serostatus by Rainbow Index and number of condomless non-steady sex partners (n=90,884)



The analyses showed similar trends for anxiety/depression. The interaction of the Rainbow Index and anxiety/depression shaped GBMSM's predictive probability of self-reported HIV positive serostatus. The predictive probability of an HIV positive serostatus was lowest among participants who did not report anxiety/depression. The predictive probability of an HIV positive serostatus was further reduced with higher Rainbow Index scores across all levels of anxiety/depression. However, GBMSM with a "severe" score on the PHQ-4 scale experienced a smaller rate of change in probability of an HIV positive serostatus as the Rainbow Index score got higher, although its initial predictive probability value was also lower (Figure 8). For example, participants with a severe score on the anxiety/depression scale who lived in a country with a Rainbow Index score of 20 (low protections) would have approximately a 19% chance of having an HIV positive status. The same participant who lived in a country with Rainbow Index score of 80 (high protections) would have a 12% chance of having HIV.

Figure 8. Predictive probability of self-reported HIV positive serostatus by Rainbow Index and anxiety/depression (n=90,884)



Supplementary self-reported HIV testing results

Among the larger sample of 125,790, 79% (n=99,149) ever had an HIV test, and 21% (n=26,641) stated they have never tested. Among non-testers, 46% (n=12,132) were in Western Europe, 36% (n=9,573) in Central Europe and 19% (4,936) were in Eastern Europe (p<0.000, Table 20). Most testers lived in European Union countries that joined before 2004, 75% (n=74,180, p<0.000). Among non-testers, 64% (n=16,829) had zero steady male sexual partners in the last 12 months and 25% (n=6,463) had one steady male partner in the last 12 months. Additionally, 39% (n=10,263) of non-testers had zero non-steady male sexual partners in the last 12 months and 12% (n=3,203) had one non-steady sexual male partner in the last 12 months, opposite of testers, who had more sexual partners (p<0.000). GBMSM that didn't test for HIV also had a lower frequency of condomless sex with non-steady partners (p<0.000). GBMSM in Western Europe, as compared to Central and Eastern Europe, had a higher frequency of non-steady sexual partners in the last 12 months (p<0.000). For steady sexual partners, GBMSM in Eastern European were more likely to have more steady sexual partners, as compared to Western and Central Europe (p<0.000).

Table 20. HIV Testing, Geography, and Sex Partners (n=125,790)

	HIV Testing, Ever		
	Not tested (%)	**Tested (%)**	**p-value**
Rainbow Index			
Low (poor policies)	8,536 (33.6)	28,518 (29.7)	0.000
Medium	8,331 (32.8)	25,723 (26.8)	
High (good policies)	8,574 (33.7)	41,677 (43.5)	
Geographic region			
Western Europe	12,132 (45.5)	54,718 (55.2)	0.000
Central Europe	9573 (35.9)	29,472 (29.7)	
Eastern Europe	4,936 (18.5)	14,959 (15.1)	
EU status			
Joined before 2004	18,103 (68.0)	74,180 (74.8)	0.000
Not joined before 2004	8,538 (32.1)	24,969 (25.2)	
Numberless of non-steady condomless sex partners in last 12 months			

Zero	18,507 (71.9)	54,195 (57.2)	0.000
1-10	6,768 (26.3)	33,481 (35.4)	
11-20	274 (1.1)	3,355 (3.5)	
21-30	67 (0.3)	1,410 (1.5)	
31-40	26 (0.1)	585 (0.6)	
41-50	21 (0.1)	362 (0.4)	
51+	67 (0.3)	1,310 (1.4)	
Numberless of steady sex partners in last 12 months			
None	16,829 (63.7)	47,943 (48.8)	0.000
One	6,463 (24.5)	33,032 (33.6)	
Two	1,424 (5.4)	6,928 (7.1)	
Three	657 (2.5)	3,567 (3.6)	
Four	277 (1.1)	1,651 (1.7)	
Five	232 (0.9)	1,217 (1.2)	
Six	91 (0.3)	619 (0.6)	
Seven	62 (0.2)	290 (0.3)	
Eight	41 (0.2)	281 (0.3)	
Nine	22 (0.1)	88 (0.1)	
Ten or more	303 (1.2)	2,618 (2.7)	
Numberless of non-steady sex partners in last 12 months			0.000
None	10,263 (39.1)	21,009 (21.5)	
One	3,203 (12.2)	6,809 (7.0)	
Two	2,877 (11.0)	7,929 (8.1)	
Three	2,246 (8.6)	7,425 (7.6)	
Four	1,503 (5.7)	5,508 (5.7)	
Five	1,275 (4.9)	6,188 (6.3)	
Six	794 (3.0)	3,916 (4.0)	
Seven	436 (1.7)	2,174 (2.2)	
Eight	412 (1.6)	2,418 (2.5)	
Nine	132 (0.5)	758 (0.8)	
Ten	822 (3.1)	5,521 (5.7)	
11-20	1,378 (5.3)	12,989 (13.3)	
21-30	438 (1.7)	5,772 (5.9)	
31-40	159 (0.6)	2,608 (2.7)	
41-50	80 (0.3)	1,605 (1.7)	
51+	243 (0.9)	4,934 (5.1)	

Discussion

Country-level policies interacted with downstream social determinants to influence self-reported HIV serostatus among GBMSM in Europe. The analysis of the EMIS database showed that European GBMSM living in countries with more protective national policies for SGM persons had lower predictive probabilities of HIV positive serostatus, even when individual-level risk factors for HIV were present. These findings provide evidence that policies can act as a significant structural determinant of HIV risk in Europe. The results confirm the hypothesis generated in the ABM analyses for aim two and confirmed the hypothesis posited in aim three, which indicated that policies have a role in inducing the emergence of HIV diagnosis.

Globally, the structural determinants of health are critical points of intervention to improve HIV prevention efforts. As the findings presented in this chapter show, country-level policies interact with downstream factors such as condomless sex and anxiety/depression to influence self-reported HIV prevalence. Previous research has shown how stigmatizing contexts can hamper HIV prevention efforts and risk behaviors. Pachankis et al. found that structural stigma toward sexual minority immigrants in Europe was associated with lower HIV-prevention knowledge, service coverage, and risk-reducing behaviors among migrants (Pachankis et al., 2017a). A global study by Arreola et al. indicated that participants living in countries where same-sex behaviors are criminalized, as compared to not, had reduced scores for access to free condoms, lubricant and anti-retroviral treatment (Arreola et al., 2015). Canada has identified poor mental health as a factor that shapes HIV risk and calls for multi-faceted policies that simultaneously address both intersecting health issues (Health Canada, 2013). The results of aim three indicated that interventions that address the plurality of issues that shape GBMSM's HIV risk, such as stigma, sexual behaviors, and mental health, have the opportunity to drastically reshape and shift HIV

prevention efforts in Europe.

As the analysis of the EMIS data showed, laws and policies are important factors to explore in the study of population health disparities related to HIV. The use of legal epidemiology can strengthen future research in this area. Legal epidemiology is the scientific study of law as a factor in the "cause, distribution, and prevention of disease" and health inequity (Ramanathan et al., 2017). Exploring how policies may influence HIV risk and infection via intermediate social determinants is a substantial gap in the research literature. By using legal epidemiology, it allows for the exploration of how the prevalence and content of the laws can influence population-level HIV disparities. The epidemiological consequences of such policy-level stigma must fully be encompassed in our conceptualizations of HIV risk to adequately intervene (Pantelic et al., 2019). This dissertation chapter adds to the global policy literature by estimating how LGBTQ+ rights and policies, or lack thereof, can shape complex processes that influence self-reported HIV serostatus.

Future research could explore which of the policies and laws reviewed within the Rainbow Index has the biggest influence on HIV serostatus and intermediary risk factors. The use of latent variable modeling could parse specific policies' roles in socially patterning HIV risk factors and diagnosis. Analytically, the use of generalized linear latent and mixed models (GLLAMM) could be useful to explain each specific policy's influence on self-reported HIV diagnosis (Skrondal & Rabe-Hesketh, 2003). Exploring how changes in policies and laws shape HIV diagnoses would also improve our knowledge about HIV (in)equity, in line with legal epidemiology. Similar exploration of the Rainbow Index and its influence on other health outcomes among SGM populations would support policy making. A previous EMIS study was conducted in 2010. Future work could utilize a serial cross-sectional design to provide an additional nuanced exploration of

how changing policies' might influence HIV risk and diagnosis (European Centre for Disease Prevention & Control, 2013). The described structural-level analyses and incorporation into prevention efforts would improve HIV programming globally.

Limitations and future research

As with all studies, limitations to the analyses exist. Firstly, the study is cross-sectional, which hinders the capacity to make causal inferences. I included critical confounding variables that were associated with HIV risk and diagnoses in bivariate analyses to mitigate this limitation. It also seems challenging to invoke reverse causation that HIV status or condomless sexual partners influence the Rainbow Index, which measures complicated policy-making processes. Secondly, given that recruitment occurred by NGOs, social media, and geospatial apps, selection bias is a concern, and the results may not be generalizable outside the study population. This could explain why the HIV testing results do not align with my hypotheses and theoretical framework. Selection bias may have inadvertently found GBMSM who were more connected to NGOs and more likely to use services, such as HIV testing. Research efforts to investigate how structural stigma influences desires and capacities for HIV testing would further differentiate the role policies play in shaping one's risk for HIV. Additional research is also needed to assess these relationships in different cultural contexts (e.g., Eastern Europe vs. Western Europe) where stigmatizing norms and process may vary (Hylton et al., 2017; King et al., 2013; Lunze et al., 2017; Saadat, 2016; Stojanovski et al., 2019; Stojisavljevic et al., 2017). The use of improved random sampling, such as venue-based time sampling or respondent-driven sampling with diverse social networks could help to address issues of selection bias, if used appropriately. Thirdly, the sample was largely concentrated in Western Europe. The use of additional sampling methods could help to improve response rates in Central and Eastern Europe, which had comparatively lower sample sizes than in

Western Europe in the analyses. Fourthly, the use of secondary data also created limitations on the operationalization of the variables in the models and their interpretation (e.g., abuse was a three-question variable), and the HIV testing and serostatus outcomes were self-reported. The large sample size would also, in many instances, be able to detect significant findings, which may not necessarily be clinically relevant (as seen in some of the analyses where the odds ratios were small). However, the main analyses of interest are the predictive probabilities, rather than each respective variable's odds ratios, which aligns with the system science approached used in this dissertation. Lastly, given that no personal identifiers, including IP addresses, were collected it is possible that persons could take the survey twice. However, given that no stipends were used, the incentive to do so would be limited.

Conclusion

Policies interact with downstream social determinants (condomless sex and anxiety/depression) to elevate the probability of an HIV positive serostatus among GBMSM in Europe. As the findings showed, supportive policy environments can help to reduce the probability of living with HIV. Given the interactional relationship between policies, condomless sex, and anxiety/depression, systems science conceptualizations of HIV risk that further explore the role of policies could enhance HIV prevention and research efforts.

Chapter 5: Discussion and Conclusion

Dissertation summary

The objective of this dissertation was to examine stigma's role in socially patterning and creating the emergence of HIV risk and diagnosis among European GBMSM. This dissertation found that HIV risk is a dynamic process influenced by numerous interacting factors and feedback loops shaped by stigmatizing policies and norms. The dissertation challenges how we conceptualize HIV risk among GBMSM, a population that is inequitably burdened by the HIV epidemic, in Europe and globally. I utilized Complex Systems Theory to reveal how the interacting pathways of stigmatizing policies and norms shape poor mental health and influence sexual behaviors that socially pattern HIV risk. For aim one (**Specific aim one**: To develop a conceptual model and visualization of HIV risk that reflects stigma's role in the epidemic among European GBMSM using Complex Systems Theory), the complex systems visualization depicted the dynamic and interacting factors emanating from structural stigma that shaped HIV risk for GBMSM in Europe. In aim two (**Specific aim two:** To understand to what extent "stigmatizing policies" influence HIV prevalence and other direct and indirect risk factors among European GBMSM in a simulated agent-based model), the computational agent-based model (ABM) showed that the cumulative result of the interacting relationships between risk factors created an emergent effect that shaped HIV "diagnosis." For aim three (**Specific aim three:** To assess to what extent countries' LGBTQ+ policies interact with downstream individual-level factors to influence GBMSM's HIV serostatus using European empirical data), using multilevel models, the results

indicated that country-level policies that stigmatize LGBTQ+ populations interact with downstream sexual risk behaviors & mental health indicators of anxiety and depression to elevate the probability of an HIV-positive serostatus among GBMSM in Europe. In totality, this dissertation expounded on how HIV risk emerged from the amalgamation of stochastic and heterogenous factors that interact, in concert, to socially pattern HIV disparities among European GBMSM—indicating the complex nature behind HIV risk.

Complex Systems Theory provided a novel framework to explore how population-level HIV inequities are produced by dynamic processes and interconnected relationships that burden GBMSM in Europe with the disparities. These factors included policies and laws that support the inclusion of SGM persons, mental health, community assets, services, social relationships, and individual-level factors such as sexual behaviors. The structural factors, such as stigmatizing policies, including lack of resource allocation, seemed to perpetuate an environment that was detrimental to individual HIV prevention efforts. Unfortunately, to date much of the HIV prevention research often focuses on examining one intervention at a time and in isolation from others (Brown et al., 2015). This dissertation indicated that European GBMSM's HIV risk emerges from numerous traversing and overlapping risk factors, and thus may similarly require complex and multifaceted interventions to adequately intervene on the myriad of factors that (re)produced HIV risk.

Complex systems and implications for HIV research in Europe

As previously described, HIV inequities exist in the WHO European Region, and modelling the factors that shape inequities is instrumental. Briefly, in the region, HIV incidence increased by 9% from 2010-2019 (European Centre for Disease Prevention and Control, 2020). In Eastern Europe, the incidence rate increased by 23% from 2010-2019 (33.9 per 100,000 in 2010

to 41.7 in 2019) (European Centre for Disease Prevention and Control, 2020). In Central Europe, the incidence rate increased by 113% from 1.6 cases per 100,000 to 3.4 cases per 100,000. While, in Western Europe, incidence decreased by 24% from 7.5 cases per 100,000 to 5.7 cases per 100,000 (European Centre for Disease Prevention and Control, 2020). GBMSM in Europe experience elevated risk. In the European Union/European Economic Area, sex between men is the main route of HIV transmission, accounting for 39% of all incident cases in 2019 (European Centre for Disease Prevention and Control, 2020). Sex between men accounted for more than 60% of incident HIV cases in 10 countries—Croatia, Czechia, Germany, Hungary, Iceland, the Netherlands, Poland, Slovakia, Slovenia and Spain—when the mode of transmission was known (European Centre for Disease Prevention and Control, 2020). In Central Europe, the male-to-female ratio was 5.5 times higher than in Western or Eastern Europe (European Centre for Disease Prevention and Control, 2020). These statistics portray the elevated burden of HIV risk that GBMSM in Europe experience.

The use of systems science has the capacity to elevate science and research to better understand the real-world processes that produce HIV inequities. The application of systems science research has expanded and been more widely supported over the last decade (Diez Roux, 2011; Duran & Pérez-Stable, 2019; Langellier et al., 2019; Luke & Stamatakis, 2012; Marshall et al., 2012). Systems science has been applied to diverse public health issues, such as HIV, urban health, and obesity, to name a few. As Skinner and Foster (2013) noted in their application of systems science to childhood obesity: “Systems science offers a means of identifying and understanding the complex relationships involved in public health policies. It recognizes that policies are based on complex, interdependent and evolving relationships and include heterogeneous agents (e.g., individuals, companies or civic associations) acting in their own

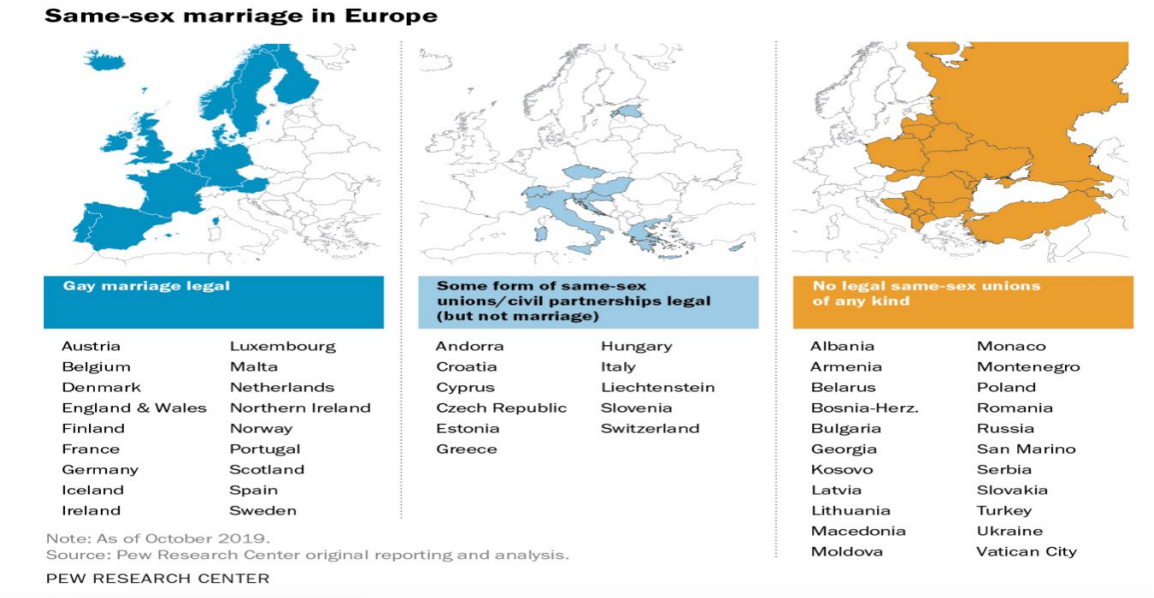
perceived self-interests. Time matters, as relationships among the agents have a history and, as a result, can develop stability or even inertia. In a complex system, intervention in one aspect will have unanticipated effects, often delayed and non-linear. **Such effects are not exceptions but the norm**." Future research could benefit from a closer examination of how the emerging effects of multiple interventions, policies, and the community, interpersonal, and individual-level risk factors all serve to co-create HIV risk and diagnosis (i.e., the norm), rather than the exception (i.e., those who have been able to prevent HIV in spite of the structural forces).

A previous complex system study of HIV found that both diagnosing PLHIV, and linking them to treatment, are needed to create a cumulative effect that reduces annual HIV infections by 25% (Gopalappa et al., 2017). Multiple combinations of percentage of PLHIV diagnosed and achieving viral suppression could achieve 25% reductions. When 85% of PLHIV were diagnosed in the model and 68% achieved viral suppression, infections could be reduced by 25%; similarly, if 90% of PLHIV were diagnosed, then only 59% would need to be virally suppressed to achieve a 25% reduction (Gopalappa et al., 2017). Another HIV system science study found that risk perceptions for HIV, sexual behaviors, and HIV transmission all co-evolve together to shape risk (Tully et al., 2013). As the model progressed, agents living with HIV had lower perceived risk that their sexual partner was also living with HIV, while for negative agents, the perceived risk was higher, and "perceptions" changed as the prevalence of HIV increased in the model (Tully et al., 2013). However, systems science research on HIV has thus far predominately been focused on the U.S. As this dissertation research showed, the interdependent and coevolving processes that stigma generates served to socially pattern HIV risk factors and infection among GBMSM in Europe.

Policy and legal contexts are important factors to consider in the modeling of health behaviors and study of HIV disparities in Europe. The heterogenous policy and legal frameworks

for SGM persons in Europe are vast. As seen in Figure 9, 16 countries recognize same-sex marriages, an additional 12 nations recognize and perform same-sex unions, and 22 do not allow same-sex unions of any kind (Lipka & Masci, 2019).

Figure 9. Same-sex marriage across Europe, 2019



Source: https://www.pewresearch.org/fact-tank/2019/10/28/where-europe-stands-on-gay-marriage-and-civil-unions/

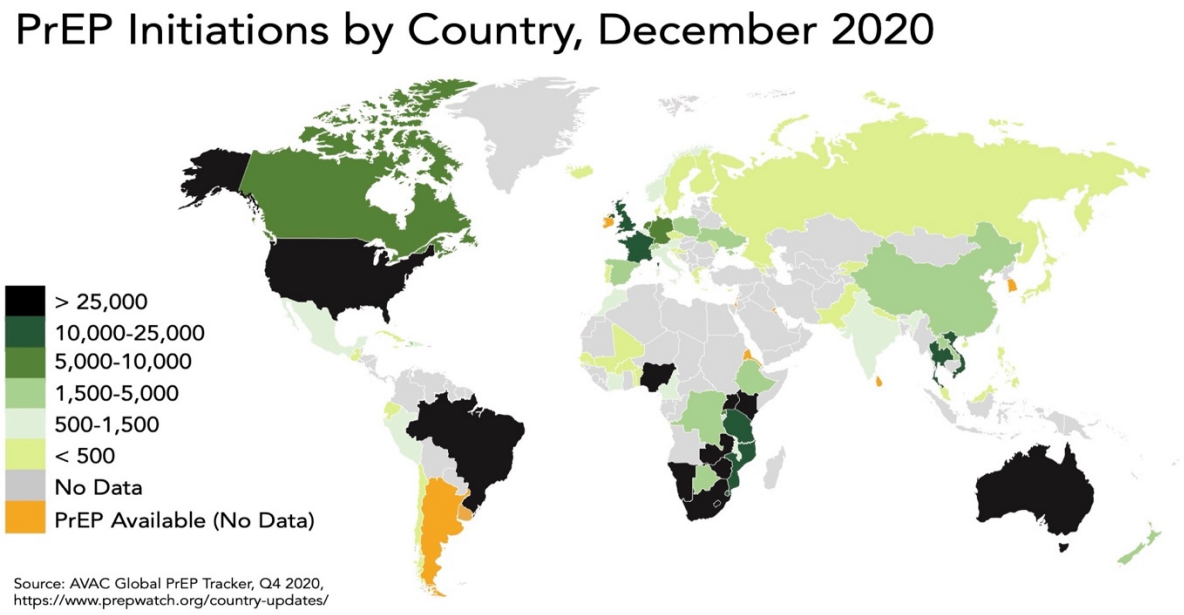
No country in Eastern Europe allows for same -sex marriage and four allow for same-sex unions (Lipka & Masci, 2019). The policy landscape is also rapidly shifting in both directions. For example, in 2020, the Hungarian (an EU nation) government banned same-sex adoptions and erased the existence of transgender individuals in the country by denying them the ability to change their gender on legal documents (Bonny, 2020). In 2020 Poland (an EU nation), one-third of the country is considered an "LGBTQ+ free zone" (Bonny, 2020). In response, the EU declared the whole EU region an LGBTQ+ Freedom Zone, stating, "LGBTIQ persons everywhere in the EU should enjoy the freedom to live and publicly show their sexual orientation and gender identity without fear of intolerance, discrimination or persecution" (BBC News, 2021). While important,

the gesture was largely symbolic and did not attach any conditions for ensuring the human rights of SGM persons. Recently, October 2020, North Macedonia (a EU enlargement area country) readopted an anti-discrimination law that protects against sexual orientation and gender identity (SOGI) discrimination (Законот За Спречување и Заштита Од Дискриминација, 2020). As another example, a lesbian couple sued Bulgaria (an EU nation) in the Court of Justice of the European Union because of the Bulgarian government's refusal to issue a birth certificate to their adopted child (Batha, 2021). These examples portray the varying and ever-evolving policies that may shape SGM persons lives in Europe. Relatedly, these issues may shape individual-level risk behaviors. This dissertation's findings indicated that policy's influence may be particularly important for GBMSM that have higher risk sexual behaviors because the policies induce those behaviors. For example, unpublished qualitative scholarship in Bosnia & Herzegovina indicates that the lack of policies for same-sex marriage or civil unions may induce riskier sexual behaviors where GBMSM have more frequent non-steady partners because they do not have a vision for future long-term relationship (due to the policy context) (Stojisavljevic et al., 2021). As a participant from the study said, "Today one partner, tomorrow another one, and no one is suspicious that you are gay" (Stojisavljevic et al., 2021). The use of complex systems, as this dissertation posited, can improve future HIV research agendas to better examine how national policies (and their changing nature) may create the environments that elevate HIV risk among GBMSM in Europe.

The use of legal epidemiology, which studies how laws pattern, shape, and produce health can further enhance our understanding of how policies influence health disparities (Ramanathan et al., 2017). As this dissertation's findings suggested, living in high stigma contexts may create barriers to HIV prevention services, such as access to condoms, PrEP, and treatment due to fears

of disclosure of identity and limited national strategies and guidelines that incorporate new prevention and treatment efforts. A recent global study examined HIV policy alignment with global norms (e.g., World Health Organization guidelines about immediate ARV treatment for PLHIV) (Kavanagh et al., 2020). Kavanagh et al. found that from 2010-2019, new HIV infections fell by 38% in southern Africa, while increasing by 72% in Eastern Europe and Central Asia (EECA) (Kavanagh et al., 2020). Many countries in southern Africa have aligned their policies with global prevention norms (e.g., immediate start of HIV treatment), while only a few countries' policies in EECA were aligned (Kavanagh et al., 2020). And in certain Western European nations, such as France, Italy, and the United Kingdom there have been greater policy adoptions aligned with international standards (Kavanagh et al., 2020). Moreover, there is variation in Europe in terms of PrEP policies and utilization, such that most countries with PrEP policies and usage in Europe are in the West, as seen in Figure 10.

Figure 10. Frequency of PrEP initiations by country, December 2020



Source: AVAC Global PrEP Tracker, Q4 2020, https://www.prepwatch.org/country-updates

As this dissertation posited, policy and legal landscapes can have serious detrimental impacts on the ability to provide services, shaping of SGM person's mental health, and alterations to HIV prevention and risk behaviors in Europe. The current and changing policy landscapes in the European continent, make future research into this area even more critical, particularly of longitudinal nature, to examine the causal effects of such policy changes.

Relatedly, there are diverse norms that "govern" society in Europe, similar to those explored in this dissertation. Such norms vary by country, and in some European nations cultural norms are violent toward GBMSM, and other SGM groups. In Slovenia, the heteronormative society influences SGM people's lives and SGM persons reported having to "mimic" the (heteronormative) society and "censor" oneself (Kuhar, 2016). In, Bulgaria there were legal changes that occurred as part of EU polices and accession to improve SGM rights (Roseneil & Stoilova, 2016). However, Roseneil & Stoilova posit that the limited bottom-up social pressures for the changes has also limited penetration of SGM issues and acceptance among the general public (Roseneil & Stoilova, 2016). Majority of citizens in all 15 countries of Western Europe support same-sex marriage, including 75% of Swiss adults, 60% of Italians, and over 80% in the Netherlands, Sweden and Denmark (Lipka & Masci, 2019). Although general attitudes may be more accepting in Western Europe, gay marriage policies were not without backlash, for example in France, and are not fully inclusive, such as in Switzerland (Reuters Staff, 2016; The Local, 2017). In terms of attitudes in Eastern Europe, the opposite pattern is seen. In Russia 5% approve of gay marriage, 9% in Ukraine, 27% in Hungary, and 32% in Poland. Only Czechia, out of the 19 countries in Central and Eastern Europe, had a majority of supporting gay marriage (Lipka & Masci, 2019). The cultural and social institutional norms may themselves shape HIV risk outside their role in shaping policy. Adding additional complexity would be issues of racism and

xenophobia. For example, Roma are one of Europe's largest ethnic minorities and suffer from numerous negative impacts due to racism (Filakovska Bobakova, 2019; Janevic et al., 2015; Orton et al., 2019). Further exploration of how stigmatizing institutional norms in Europe create a complex system that perpetuates HIV disparities is critical, especially among other populations living with stigmatization that may experience additional vulnerabilities.

As the dissertation portrayed, the amalgamation of factors that are shaped by stigma can elevate HIV risk among European GBMSM. A growing body of global scholarship provides causal evidence of the stigmatizing pathways that socially pattern and shape HIV risk and infection among GBMSM that this dissertation studied. In a U.S.-based longitudinal study from 1999 to 2001 among 4,295 GBMSM, Mimiaga et al. found that over time HIV seroconversions were highest among GBMSM living with more psychosocial problems (e.g., depression, childhood sexual abuse, heavy alcohol use and drug use) (Mimiaga et al., 2015). The hazards of seroconverting were 8.7 times higher among those with four or five psychosocial conditions, 5.3 times higher for those with three conditions, 2.4 times the hazard for those with two conditions, and 1.7 times higher for those with one condition, as compared to men who had no psychosocial conditions (Mimiaga et al., 2015). The cumulative effect of multiple psychosocial conditions was still present after the partially mediated effect of sexual risk behavior was taken into account. Longitudinal analyses have also been conducted with other stigmatized groups, such as transgender women. In a prospective study from 2012-2015 among transgender women in the U.S., women who had more psychosocial issues had higher risk of participating in condomless anal and vaginal sex, as compared to those with no psychosocial conditions (Mimiaga et al., 2019). Among South African women from 2011 to 2013, women who experienced depression were less adherent to their PrEP regimen (Velloza et al., 2020). Linking complex systems to these global studies

indicates that the psychosocial issues GBMSM experience, such as mental health, are socially patterned, which then act as important risk factors for HIV that require immediate attention to enhance HIV prevention efforts in Europe, and arguably, globally. Further causal research is needed among European GBMSM, and other stigmatized populations, to better elucidate the pathways within the complex systems that shape their risk of HIV.

While important, the psychosocial conditions that elevate HIV risk are themselves patterned by the complex system of structural forces. Stigma's role in challenging the mental health of key populations indicates that additional structural-level interventions are needed to enhance HIV prevention efforts. As this dissertation showed, stigma perpetuates adverse outcomes for mental health, which in turn may shape sexual risk behaviors. In addition, mental health professionals might themselves be the enactor of stigma, thus further patterning the HIV risk and challenging HIV risk prevention (Schulze, 2007). Without addressing the upstream role that stigma plays, the pathways that lead to poor mental health and at-risk HIV behaviors will continue to be activated. Focusing on downstream interventions, such as developing positive coping strategies and providing mental health treatment might only achieve small or modest impact. Interestingly enough the effect sizes for mental health interventions have typically been small and of a targeted nature (Sikkema et al., 2010). Adding to the challenges, mental health services and professionals are scarce globally, and particularly in Eastern Europe (Dlouhy, 2014; Krupchanka D. & Winkler, 2016). Interventions that aim to integrate HIV and mental health services are also rare in low- and middle- income countries (Chuah et al., 2017). This scarcity further hampers efforts to intervene on mental health, which indicates that other sites of intervention may be more appropriate to alleviate the effects of stigma. As this dissertation posited, structural interventions, in the form of improving policies that protect GBMSM and other SGM communities, could help to address

stigma's role in shaping the environment that (re)produces HIV risk, rather than focusing on the intermediate or downstream risk factors.

Complex systems and implications for global HIV research

Global HIV and SGM research has advanced rapidly. This dissertation adds to the global public health research literature by identifying specific pathways within a complex system that drive HIV disparities toward GBMSM in Europe. The dissertation showcases a need for improved training and research methods to study the complex system that socially pattern the health behaviors. As Petteway (2020) states,

"Perhaps it is time that the field of health education and health promotion wash its hands of decades of decontextualized, apolitical, individualist behavior change ideology and more expressly and urgently call for and demonstrate a more critical data practice—one of resistance and counternarrative, so as to disrupt its history of epistemic violence, especially in times of public health crises" (Petteway, 2020).

This dissertation builds the evidence for the "counternarrative" to our current conceptualizations of HIV risk. The dissertation shifted the attention from the individual risk behaviors and prevention efforts, to situating the behaviors within the complex political, societal, and communal context in which they must be performed. The use of systems science approaches to study HIV in Europe augments current global SGM and HIV health research theories, methods and practice. Future research efforts could benefit from further exploring how the health behaviors of GBMSM are manipulated by systems of oppression and marginalization, as this dissertation indicated is important. As one example, the Theory of Planned Behavior, a widely used health behavior theory, posits that attitudes, subjective norms, and behavioral intention are important

constructs that shape behaviors, such as condom use (Ajzen, 1991). However, how might the subjective norms and attitudes themselves be manipulated by the structural environments in which GBMSM live? Future research efforts would benefit from continuing to understand how the system of diverse factors can shape HIV risk. Qualitative research with GBMSM in different European countries with different policy contexts (and changing contexts) could help to further situate the risk factors for HIV by exploring how the structural contexts may shape them. This dissertation showcased that improving the LGBTQ+ policy landscape can help to mitigate HIV disparities given policies' roles in inducing some of the processes that lead to HIV risk. It is imperative that European nations continue to create the policy conditions for GBMSM, and other lesbian, transgender and queer citizens to live authentically, which can help to alleviate health disparities. Future research should examine how best to support bottom-up community organizing and activism so that such efforts may be leveraged in other countries with hostile government policies and to simultaneously alter the societal norms. As one example, conducting psychoeducation with SGM communities on how structural stigmatization influences their lives may provide impetus for communities to get involved in activism, to shape the structural conditions, while also improving downstream mental health (Burton et al., 2019; Cook et al., 2014). The dynamic and interactional nature of HIV risk should be the focus of interventions, including through policies, and not simply on the downstream factors that emerge from the complex system. Future research should similarly examine how the changing stigmatizing policies may shape other LGBTQ+ health outcomes.

Conclusion

This dissertation elucidated and challenged how we conceptualize HIV risk among GBMSM in Europe, a population that is inequitably burdened by the HIV epidemic. This dissertation utilized Complex Systems Theory, computational agent-based modeling, and multi-level modeling to study how the interacting pathways of limited policy protections can influence downstream determinants such as mental health and sexual behaviors to socially pattern HIV risk among GBMSM in Europe. The complex systems visualization in Chapter two revealed that HIV risk among GBMSM in Europe arises from intersecting and interacting factors emanating from stigmatizing contexts. The agent-based model in Chapter three explored how stigmatizing policies shape intermediary mental health and health behaviors that influenced HIV risks and diagnoses. The ABM exhibited the dynamic processes and relationships between diverse risk factors that generated a cumulative and emerging effect that elevated HIV risk and diagnosis among GBMSM in the model. For Chapter four, the use of empirical data and multi-level modelling identified that country-level policies interacted with downstream sexual behaviors and anxiety/depression to heighten the probability of an HIV positive serostatus. In conclusion, this dissertation adds to the scientific literature by understanding the dynamic nature of HIV risk by exploring how stigmatizing policies and their influence on diverse downstream and interacting determinants operate to elevate HIV risk among GBMSM in Europe. This dissertation's research findings call attention to the need for developing interventions that are as complex as the dynamic forces that cumulatively perpetuate HIV disparities. HIV prevention, research and policy efforts would

benefit from improved incorporation of structural interventions to adequately address the cumulative effect of heterogenous factors that shape HIV risk to support European and global HIV goals.

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Appendices

Appendix I: Python code of agent-based model

```
import matplotlib
import sys
import pylab as PL
import random as rd
import math
import numpy as np
import pandas as pd
from multiprocessing import Process, Manager

# ------------------------------ helper functions ------------------------------------#
# calculate distance between agent m and agent n
def cal_dis(total_pop, m, n):
    return math.sqrt((total_pop[m][0][0] - total_pop[n][0][0]) ** 2 + (total_pop[m][0][1] -
total_pop[n][0][1]) ** 2)

# check if two agent satisfy their preferred # of partner conditions
def check_PN(tidx, bidx, total_pop):
    # if they haven't had sex before
    if (tidx,bidx) not in total_pop[tidx][7]:
        # if the number of past sex partners doesnt reach PN
        if len(total_pop[tidx][7]) < total_pop[tidx][6] and len(total_pop[bidx][7]) <
total_pop[bidx][6]:
            return True
        else:
            return False
    return True # if they already had sex

# set the initial values for preferred number of sexual partners
def init_PN():
    # 0: none, 1: 1-4, 2: 5-10, 3: 11-50, 4: > 50
    #returns 0 or random values within each range: 1-4, 5-10, 11-50, 50+
    #p=percentage within each range
    range = np.random.choice(np.arange(0, 5), p=[0.2,0.45,0.1,0.2,0.05])
    if range == 0:
        return 0
    elif range == 1:
```

```
        return rd.randint(1, 4)
    elif range == 2:
        return rd.randint(5,10)
    elif range == 3:
        return rd.randint(11,50)
    else:
        return rd.randint(50, 100)

#flip coin for sexual encounters?
def flip_coin(idx, coin_odds, total_pop):
    zero_prob = 1 - float(1 / (1 + coin_odds * total_pop[idx][2]))
    return np.random.choice(np.arange(0, 2), p=[zero_prob, 1-zero_prob])

#update pairs of sexual partners; top and bottom pairs
def update_pairs(tidx, bidx, total_pop):
    if (tidx,bidx) not in total_pop[tidx][7]:
        total_pop[tidx][7].update([(tidx, bidx)])
        total_pop[bidx][7].update([(bidx, tidx)])

#HIV infection function
# [5] 0=no HIV, 1=HIV+ undetectable (udHIV); 2=HIV+ known (dkHIV); 3=HIV+ unknown
(duHIV)
def get_infect(infect_prob, udHIV_prob, dKHIV_prob, dUHIV_prob):
    return np.random.choice(np.arange(0, 4), p=[1-infect_prob, infect_prob*udHIV_prob,
infect_prob*dKHIV_prob, infect_prob*dUHIV_prob])

#check and count infections
def check_infect(infect_prob, use_condom, idx, udHIV_prob, dKHIV_prob, dUHIV_prob,
dates):
    if (use_condom):
        reduce_prob = np.random.uniform(0,0.3) * infect_prob # reduces probability of infection by
70-100%
        infect = get_infect(reduce_prob, udHIV_prob, dKHIV_prob, dUHIV_prob)
    else:
        infect = get_infect(infect_prob, udHIV_prob, dKHIV_prob, dUHIV_prob)
    if (infect != 0):
        if infect == 2 or infect == 3:
            dates[idx] = 0
    return infect
# ------------------------------------------------------------------------------ #

#initialize the parameters and their values
def init(pop_num, width, height, gay_prob, nHIV_prob, udHIV_prob, dKHIV_prob,
dUHIV_prob, dates):
    total_pop = []
    gay_num = 0
```

```
    ngay_num = 0
    for i in range(pop_num):
        location = [rd.randint(0, width), rd.randint(0, height)] # set initial location
        is_gay = np.random.choice(np.arange(0, 2), p=[1-gay_prob, gay_prob]) # set gay or non-
gay
        #if gay agent put into their array the variables in gray below
        if is_gay:
            #setting the initial probabilities for HIV rates, 0=no HIV, 1=HIV+ undetectable, 2=HIV+
known, 3=HIV+ unknown
            HIV = np.random.choice(np.arange(0, 4), p=[nHIV_prob, (1-nHIV_prob)*udHIV_prob,
(1-nHIV_prob)*dKHIV_prob, (1-nHIV_prob)*dUHIV_prob])
            if HIV == 2 or HIV == 3:
                dates[i] = 0
            homonegativity = min(max(0,rd.gauss(0.0018689,0.0694458)),6) #setting
homonegativity
            condom = round(1 - homonegativity/6) #setting condom use
            CSB = min(max(0, rd.gauss(0.0052334,0.0996636)), 65) #setting compulsive sexual
behavior
            #parameters of the gay agents
            # [0] location, [1] is_gay, [2] homonegativity,
            # [3] condom usage, [4] compulsive sexual behavior, [5] HIV status,
            # [6] preferred number of partners, [7] unique pairs of partners, [8] ID
            total_pop.append([location, is_gay, homonegativity, condom, CSB, HIV]) #array of
parameters
            #increase count of gay agents and HIV if not zero
            gay_num += 1

        #parameters for non-gay agents
        else:
            # [0] location, [1] is_gay, [2] discrimination
            total_pop.append([location, is_gay, min(max(0,rd.gauss(0.0388906,0.7092845)), 100)])
#array of parameters
            ngay_num += 1


    # Initialize preferred number of partners among gay agents
    idx = 0
    for i in range(pop_num):
        if total_pop[i][1]:
            total_pop[i].append(init_PN())
            total_pop[i].append(set()) # to record pairs of unique partners
            total_pop[i].append(idx)
            idx += 1

    return total_pop, gay_num, ngay_num
```

```
#step function, which ticks time forward one
def step(earth, policy, width, height, step_move,
    meet_distance, ncon_prob, con_prob, nHIV_prob, dKHIV_prob,
    dUHIV_prob, udHIV_prob, dU_to_dK_prob, dK_to_ud_prob, infect_top_prob,
    infect_bottom_prob, pop_num, arr, top_prob, gay_prob, coin_odds, maxpol,
    total_pop, time, gay_num, ngay_num, dates):

    id_list = [num for num in range(gay_num)]
    earth_list = [earth] * gay_num
    policy_list = [policy] * gay_num
    PNs_temp = [] #preferred partners for each person
    discrims_temp = np.zeros(gay_num)#average discriminaion for each gay person
    CSB_temp = [] # for each person
    homonegs_temp = [] # for each person
    HIV_status_temp = [] # for each person
    expose_num_temp = np.zeros(gay_num)
    sex_temp = np.zeros(gay_num)
    condom_use_temp = np.zeros(gay_num)
    meet_ngay_temp = np.zeros(gay_num)

    np.random.shuffle(arr) # shuffle the index array
    # policy change function
    #policy = maxpol*((-float(time)/(60+float(time)))+1) # policy gets worse over time
    #policies.append(policy)

    #for each agent in the model
    idx = 0
    for person in total_pop:
        # set the new location for each agent
        for j in range(2):
            person[0][j] = (person[0][j] + rd.randint(-step_move, step_move)) % width
        # if non-gay agent then discrimination varies
        if not person[1]:
            # first term: linear function decaying from 100 to zero over the entire policy range
            # result: average the two to get next time discrimination
            person[2] = (max(min(100 + (-float(100)/maxpol)*policy,100),0) + float(person[2])/2)
        #gay agent then homonegativity varies
        else:
            # [0] location, [1] is_gay, [2] homonegativity,
            # [3] condom usage, [4] compulsive sexual behavior, [5] HIV status,
            # [6] preferred number of partners, [7] unique pairs of partners
            PNs_temp.append(person[6])
            homonegs_temp.append(person[2])
            CSB_temp.append(person[4])
            HIV_status_temp.append(person[5])
            person[2]=min(max((person[2]+(-float(6)/maxpol)*policy+6)/2, 0), 6)
```

```
        #changing HIV statuses over time
        if idx in dates:
            dates[idx] += 1
            # [5] 0=no HIV, 1=HIV+ undetectable (udHIV); 2=HIV+ known (dkHIV); 3=HIV+
unknown (duHIV)
            if dates[idx] % 6 == 0: # every 6 months
                if dates[idx] % 12 == 0: # every 12 months
                    if person[5] == 2: # known to undetectable
                        get_treated = np.random.choice(np.arange(0, 2), p=[1-dK_to_ud_prob,
dK_to_ud_prob])
                        if get_treated:
                            person[5] = 1
                            dates.pop(idx) # remove the person from dates
                if person[5] == 3: # unknown to known HIV status
                    get_treated = np.random.choice(np.arange(0, 2), p=[1-dU_to_dK_prob,
dU_to_dK_prob])
                    if get_treated:
                        person[5] = 2
                        dates[idx] = 0
        idx += 1

    # loop through entire population
    for i in range(pop_num):
        for j in range(i+1, pop_num):
            m = arr[i]
            n = arr[j]
            # calculate geographical distance
            distance = cal_dis(total_pop,m,n)
            # if two agents meet
            if distance <= meet_distance:
                # if one agent is gay, another agent is non-gay then discrimination can occur
                if (not total_pop[m][1] and total_pop[n][1]) or (not total_pop[n][1] and
total_pop[m][1]):
                    gid = m if total_pop[m][1] else n # gay id
                    ngid = n if gid == m else m # non-gay id
                    meet_ngay_temp[total_pop[gid][8]] += 1
                    discrims_temp[total_pop[gid][8]] += total_pop[ngid][2]
                    # homonegativity(t+1) = homonegativity(t) + discrimination * 0.011(w/
variance=0.78) + policy * 0.584(w/ variance=0.00945)
                    total_pop[gid][2] = min(max((total_pop[gid][2] +
(6/100)*total_pop[ngid][2]/ngay_num)/2, 0), 6)

                # if two gay agents meet
                elif (total_pop[m][1] and total_pop[n][1]):
                    # flip a coin and decide top/bottom
                    m_is_top = np.random.choice(np.arange(0, 2), p=[1-top_prob, top_prob])
```

```
                n_is_top = np.random.choice(np.arange(0, 2), p=[1-top_prob, top_prob])
                # one top and one bottom
                if (not (m_is_top == n_is_top)):
                    tidx = m if m_is_top else n # top idx
                    bidx = n if tidx == m else m # bottom idx

                    # check PN
                    check_PN_pass = check_PN(tidx, bidx, total_pop)

                    #assess if partners will have sex
                    if check_PN_pass:
                        have_sex = -1
                        if_use_con = -1
                        # have the same opinion on condom
                        if (total_pop[m][3] == total_pop[n][3]):
                            # both want to use condom, sex with condom occurs as a function of
top/bottom & counted
                            if (total_pop[m][3] == 1):
                                if_use_con = 1
                                have_sex = sex(tidx, bidx, 1, expose_num_temp, total_pop,
infect_top_prob, infect_bottom_prob, udHIV_prob, dKHIV_prob, dUHIV_prob, dates)
                            # both don't care about condom, flip a biased to coin: bias is toward 1, which
means condom used (0.7)
                            elif (total_pop[m][3] == 0):
                                choice = flip_coin(m, coin_odds, total_pop)
                                if_use_con = choice
                                have_sex = sex(tidx, bidx, choice, expose_num_temp, total_pop,
infect_top_prob, infect_bottom_prob, udHIV_prob, dKHIV_prob, dUHIV_prob, dates)
                            # both dont want to use condom
                            else:
                                if_use_con = 0
                                have_sex =sex(tidx, bidx, 0, expose_num_temp, total_pop,
infect_top_prob, infect_bottom_prob, udHIV_prob, dKHIV_prob, dUHIV_prob, dates)

                        # one of gay agents dont care about condom
                        elif (total_pop[m][3]==0 or total_pop[n][3]==0):
                            nidx = m if total_pop[m][3]==0 else n # person doesn't care
                            idx = n if nidx == m else m # person care
                            # the person who doesnt' care about condom use
                            coin_res = flip_coin(nidx, coin_odds, total_pop)
                            # coin_res == people want to use condom == 1
                            # use condom if (1 1)
                            if (coin_res == total_pop[idx][3]):
                                have_sex = sex(tidx, bidx, 1, expose_num_temp, total_pop,
infect_top_prob, infect_bottom_prob, udHIV_prob, dKHIV_prob, dUHIV_prob, dates)
                                if_use_con = 1
```

```
                        else:
                            # person who has preference for condom flips the coin
                            new_coin_res = flip_coin(idx, coin_odds, total_pop)
                            # agree on coin result
                            if (new_coin_res == coin_res):
                                have_sex = sex(tidx, bidx, coin_res, expose_num_temp, total_pop,
infect_top_prob, infect_bottom_prob, udHIV_prob, dKHIV_prob, dUHIV_prob, dates)
                                if_use_con = coin_res
                            # else disagree so no sex
                    # else: disagree on condom use,skip
                    if have_sex == 1:
                        m_id = total_pop[m][8]
                        n_id = total_pop[n][8]
                        sex_temp[m_id] += 1
                        sex_temp[n_id] += 1
                        if if_use_con == 1:
                            condom_use_temp[m_id] += 1
                            condom_use_temp[n_id] += 1
    for i in range(len(discrims_temp)):
        if meet_ngay_temp[i] != 0:
            discrims_temp[i] = float(discrims_temp[i] / meet_ngay_temp[i])

    #updates on gay agents parameters based on equations below
    for person in total_pop:
        if person[1]:
            # CSB(t+1) = CSB(t) + 0.43 * homonegativity
            person[4] = min(max(0, (person[4] + 0.43*(float(person[2]/6)))/2), 40)
            # PN(t+1) = PN(t) - 0.15 * homonegativity + 0.8 * compulsive sexual behavior
            person[6] = min(max((person[6] - float(0.15*(person[2]/6)) +
float(0.8*(person[4]/45))/2), 0), gay_num)
            # condom(t+1) = 1-homonegativity(t)/6
            person[3] = int(1 - person[2]/6)
    return policy_list, earth_list, id_list, sex_temp, condom_use_temp, meet_ngay_temp,
expose_num_temp, CSB_temp, discrims_temp, homonegs_temp, PNs_temp, HIV_status_temp


# [5] 0=no HIV, 1=HIV+ undetectable (udHIV); 2=HIV+ known (dkHIV); 3=HIV+ unknown
(duHIV)
#determine between who the sex is occuring & use of condoms
def sex(tidx, bidx, use_condom, expose_num_temp,
    total_pop, infect_top_prob, infect_bottom_prob,
    udHIV_prob, dKHIV_prob, dUHIV_prob, dates):

    # 0=negative top
    if (total_pop[tidx][5] == 0):
        # 3=unknown detectable bottom
```

```
        if(total_pop[bidx][5] == 3):

            expose_num_temp[total_pop[tidx][8]] += 1
            total_pop[tidx][5] = check_infect(infect_top_prob, use_condom, tidx, udHIV_prob,
dKHIV_prob, dUHIV_prob, dates)
            update_pairs(tidx, bidx, total_pop)
            return 1
        # negative bottom & undetectable bottom
        elif (total_pop[bidx][5] != 2):
            update_pairs(tidx, bidx, total_pop)
            return 1
    # undetectable top
    elif (total_pop[tidx][5] == 1):
        update_pairs(tidx, bidx, total_pop)
        return 1
    # detectable top, unknown
    elif (total_pop[tidx][5] == 3) :
         # negative bottom
        if(total_pop[bidx][5] == 0):
            expose_num_temp[total_pop[bidx][8]] += 1
            total_pop[bidx][5] = check_infect(infect_bottom_prob, use_condom, bidx, udHIV_prob,
dKHIV_prob, dUHIV_prob, dates)
            update_pairs(tidx, bidx, total_pop)
            return 1
        # undetectable bottom or unknown detectable bottom
        elif (total_pop[bidx][5] != 2):
            update_pairs(tidx, bidx, total_pop)
            return 1
    return 0

def wrap(policy, earth, time_list, policy_list, earth_list, id_list, sex_list, condom_use_list,
        meet_ngay_list, expose_num_list, CSB_list, discrims_list,
        homonegs_list, PNs_list, HIV_status_list):

    # size of the map
    width = 100
    height = 100

    step_move = 10
    meet_distance = 10 # within the distance, two agents meet

    # init value
    ncon_prob = 0.5 #initial value of those not wanting to use condoms
    con_prob = 0.3 #initial value of those wanting to use condoms; 1-con_prob-ncon_prob=those
who don't care about condom use
    nHIV_prob = 0.89 # probability of negative HIV status
```

```
    dUHIV_prob = 0.4 # probability of HIV+, detectable and unknown(out of 10%)
    dKHIV_prob = 0.1 # probability of HIV+, detectable and known(out of 10%)
    udHIV_prob = 0.5 # probability of HIV+, undetectable(out of 10%)
    dU_to_dK_prob = 0.00384341 # probability of moving from unknown to known
    dK_to_ud_prob = 0.00329312 # probability of moving from known to undetectable


    infect_top_prob = 0.0011 # probability of becoming infected with HIV if a top
    infect_bottom_prob = 0.0138 # probability of becoming infected with HIV if a bottom

    pop_num = 1500 # entire population size
    arr = np.arange(pop_num)
    gay_num = 0 #initial gay population count
    ngay_num = 0 #initial non-gay population count
    top_prob = 0.5 #probablity that gay agent is a top
    gay_prob = 0.4 # percentage of gay agents
    coin_odds = 1.2 # not use condom / use condom = 1.2 * homonegativity
    maxpol = 14
    ############################

    time = 0
    dates = dict()
    total_pop, gay_num, ngay_num = init(pop_num, width, height, gay_prob, nHIV_prob,
udHIV_prob, dKHIV_prob, dUHIV_prob, dates)


    for _ in range(100):
        time_temp = [time] * gay_num
        policy_temp, earth_temp, id_temp, sex_temp, condom_use_temp,meet_ngay_temp,
expose_num_temp, CSB_temp, discrims_temp,homonegs_temp, PNs_temp, HIV_status_temp =
step(earth, policy, width, height, step_move,meet_distance, ncon_prob, con_prob, nHIV_prob,
dKHIV_prob, dUHIV_prob, udHIV_prob, dU_to_dK_prob,dK_to_ud_prob,
infect_top_prob,infect_bottom_prob, pop_num, arr, top_prob, gay_prob,coin_odds, maxpol,
total_pop, time, gay_num, ngay_num, dates)
        time += 1
        time_list.extend(time_temp)
        policy_list.extend(policy_temp)
        earth_list.extend(earth_temp)
        id_list.extend(id_temp)
        sex_list.extend(sex_temp)
        condom_use_list.extend(condom_use_temp)
        meet_ngay_list.extend(meet_ngay_temp)
        expose_num_list.extend(expose_num_temp)
        CSB_list.extend(CSB_temp)
        discrims_list.extend(discrims_temp)
        homonegs_list.extend(homonegs_temp)
```

```
        PNs_list.extend(PNs_temp)
        HIV_status_list.extend(HIV_status_temp)


if __name__ == "__main__":
    with Manager() as manager:
        policy_list = manager.list()
        earth_list = manager.list()
        id_list = manager.list()
        sex_list = manager.list()
        condom_use_list = manager.list()
        meet_ngay_list = manager.list()
        expose_num_list = manager.list()
        CSB_list = manager.list()
        discrims_list = manager.list()
        homonegs_list = manager.list()
        PNs_list = manager.list()
        HIV_status_list = manager.list()
        time_list = manager.list()
        processes = []
        policy_sweep = [14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1]
        for policy in policy_sweep:
            for earth in range(100):
                p = Process(target = wrap, args = (policy, earth, time_list, policy_list, earth_list,
id_list, sex_list, condom_use_list,
        meet_ngay_list, expose_num_list, CSB_list, discrims_list,
        homonegs_list, PNs_list, HIV_status_list))
                p.start()
                processes.append(p)
        for p in processes:
            p.join()

        data = {'time':list(time_list),'policy':list(policy_list), "population": list(earth_list), "agent id
in pop": list(id_list), "sex num": list(sex_list),
        "condom num": list(condom_use_list), "ngay_meet": list(meet_ngay_list), "expose num":
list(expose_num_list), "CSB": list(CSB_list),
        "discrims_num": list(discrims_list), "homonegs_num": list(homonegs_list), "PNs_nu,":
list(PNs_list), "HIV status":list(HIV_status_list)}
        df = pd.DataFrame(data)

        df.to_stata("HIVstigma_diffagents_pop1500_earth100_policy100_policy1-
14_policy14outputs_20201009.dta")
```